IMPERIAL MINERAL RESOURCES BUREAU.

THE MINERAL INDUSTRY OF THE BRITISH EMPIRE

AND

FOREIGN COUNTRIES.

WAR PERIOD.

PHOSPHATES.

(1913-1919.)

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PREFACE.

The following digest of statistical and technical information relative to the production, consumption and value of phosphates, will form a part of the volume or volumes on the Mineral Resources of the British Empire and Foreign Countries constituting the Annual Mineral Conspectus of the Bureau.

In this, the first year of publication, an effort has been made to fill in, as far as possible, the hiatus due to the war in the publications relating to mining and metallurgical statistics. Labour, health and safety statistics have been omitted owing to the difficulty involved in procuring reliable information for the war period, but in future issues these statistics will be included in respect of each year. Resort will also be had to graphical representation of statistics of production, consumption, costs, and prices.

The weights are expressed in long tons, that is to say, the British statute ton of 2,240 lb., and values in pounds, shillings and pence at par rates of exchange.

Sir Herbert Jackson, K.B.E., a Governor of the Imperial Mineral Resources Bureau, is Chairman of the Advisory Technical Committee which deals with phosphates, and for much of the information contained in this digest the Bureau is indebted to Mr. A. N. Gray.

(Signed) R. A. S. REDMAYNE,

Chairman of the Governors.

2, Queen Anne's Gate Buildings,

London, S.W.1.

September, 1921.

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GENERAL.

The minerals of chief importance as sources of phosphates are phosphorite and apatite. Apatite is a phosphate of lime with fluoride or chloride of calcium, containing when pure about 90 per cent. of tri-calcium phosphate and 10 per cent. of calcium fluoride or calcium chloride. Phosphorite or rock-phosphate consists of phosphate of lime, but is less definite in its chemical composition than apatite.

Crystalline apatite rarely occurs in sufficient quantity to allow of profitable mining operations. Such deposits are worked in the province of Cáceres, in Spain, and in the district of Kragerö, in Norway, while a considerable quantity of apatite is recovered during the process of mica-mining in many of the pyroxenite rocks of Canada.

Rock-phosphate varies as regards its physical condition from rocks and boulders of hard black or grey phosphate, to a soft brownish and friable material that can be removed by simple pick-and-shovel operations.

Small quantities of high-grade phosphate are obtained from limestone caves containing the bones and excrement of animals, and from certain islands largely frequented by birds. Strata containing large quantities of so-called " coprolites " were formerly an important source of phosphate fertilizers in England, France, and other European countries, but the discovery and exploitation of the United States and North African deposits of phosphate-rock have greatly reduced the value of these deposits. The coprolitic beds in England are now worked only on a small scale, to supply a strictly local demand. The Cretaceous " Greensands " contain glauconite (a hydrated silicate of iron and potassium); they are used in some countries as fertilizers, mainly on account of the potash content, but an appreciable amount of phosphatic matter is usually present, and this increases their value as fertilizers.

Massive aluminium phosphate occurs in workable deposits at some localities, as, for example, in the island of Redonda, Leeward Islands, West Indies; and at Saldanha Bay in Cape Province, South Africa.

Phosphate of lime is utilized chiefly in the manufacture of soluble superphosphate, which consists of mono-calcium phosphate of lime. The raw material known as tri-calcium phosphate, after grinding, is treated with chamber sulphuric acid, the insoluble tri-calcium phosphate being thus converted into a soluble mono-calcium phosphate and gypsum, known commercially as superphosphate or " super."

Phosphate-rock should contain at least 40 per cent. of tri-calcium phosphate for the successful manufacture of super-phosphate; second-grade superphosphate is usually required to contain from 50 to 60 per cent. tri-calcium phosphate. First-grade phosphate-rock may carry as much as 90 per cent. tri-calcium phosphate, as is the case with many of the Pacific deposits, but all phosphate-rock carrying from 60 to 80 per cent. tri-calcium phosphate may be classed as high- or first-grade rock.

The objectionable impurities in rock-phosphate are iron oxide and alumina, which cause superphosphate to revert and become insoluble. Phosphates are therefore usually sold under a guarantee that they do not contain more than 4 per cent. of those impurities. A small amount of calcium carbonate is beneficial, but fluorine, if present in considerable quantity, is objectionable.

Phosphate-rock is also used as a source of phosphorus and its chemical compounds, such as phosphoric acid.

The world's principal deposits of phosphate are found in the United States and North Africa, and to a lesser degree in the islands of the Pacific, more especially the groups lying between Australia and Japan.

The important deposits of North Africa occur in a belt running from the Atlantic in the west to Asia Minor in the east. The recently discovered deposit at El Boroudj, in Morocco, about 80 miles from the Atlantic coast, is the most westerly of the workable fields in the belt, but low-grade phosphates are found at Rabat and at many other places near the Atlantic coast of Morocco. In Morocco and Algeria they lie mostly on the northern slopes of the Atlas range, and the chain of mountains running diagonally across Algeria. The Tunisian deposits continue the series to the east and next in the chain come the low-grade deposits of Cyrenaica, which are mostly situated close to the shores of the Mediterranean. Farther east are the Egyptian deposits, and still farther the important Palestine deposit at Es Salt, to the east of the valley of the Jordan.

Although there is no workable deposit of phosphate so far known between El Boroudj and eastern Algeria, there are occurrences at various points in the intervening country between the two proved fields.

Algeria and Tunis have been more closely prospected for phosphates than has Morocco, and consequently much more evidence is available as to the character and extent of the phosphate beds.

There are several large deposits of workable extent both in Tunis and Algeria which are not being mined at present, for various reasons, the principal of which is relative inaccessibility. Phosphate is a low-priced commodity and it follows, therefore,

that those deposits which can be most economically worked as regards mining operations, and which are nearest to the sea, have been the first to receive attention. These deposits will be dealt with under the respective headings Tunis and Algeria (pp. 57-59).

The United States phosphate deposits and those of the Pacific Islands are referred to on pp. 49, 50, 60 to 65 and 67.

Europe has very few phosphate deposits of importance. A considerable quantity of low-grade rock is found in France and Belgium, as will be seen by reference to the notes under the headings of these two countries. There are also very considerable deposits in Russia, but so far as is known the beds have not been worked to any considerable extent.

In Norway apatite is mined. Australia possesses a few beds, generally speaking of low-grade phosphates, and there are some known commercial deposits of phosphate in South America.

WORLD'S PRODUCTION.

The leading producer of phosphates is the United States. France with her colonies (Algeria and Tunis) takes second place, but the phosphates produced are of lower grade than the best American "land-pebble" phosphates. The discovery of an extensive deposit of phosphate-rock has been reported from El Boroudj, in the Casablanca region of French Morocco. Sufficient exploratory work has not yet been done to prove the economic value of this deposit.

The British Empire possesses potential resources of phosphate-rock of considerable magnitude. There are extensive deposits in Egypt. In the Pacific Islands and those of the Indian Ocean there remain large reserves of high-grade rock, while both Australia and South Africa have considerable areas yet to be exploited. Canada formerly produced large quantities of apatite, and still has considerable resources of this mineral.

During the war the phosphate-mining industry throughout the world suffered severely. This was particularly the case with the Florida "hard-rock" material, the greater part of which is mined for export. The causes of the decline were principally lack of transport facilities and inability to obtain adequate quantities of sulphuric acid, due to the fact that large amounts were used in the manufacture of munitions of war.

In the period immediately preceding the war, production had attained large dimensions, and there was undoubtedly a great and ever-increasing demand for phosphate. It seems clear, however, that the tendency was for the production to outstrip the demand, seeing that for some years prior to 1913 the trend of prices had been steadily downward.

According to the most reliable authorities, production had risen from about 4½ million tons in 1907 to about 7 million tons in 1913, the figures from year to year showing a progressive increase. This great expansion in production was most marked in Tunis and the United States, but the Pacific Islands also show a very considerable increase in output during that period.

It will be observed from the statistics appended that, as a result of the war, the world's production fell rapidly, the total output in 1914 being rather less than 80 per cent. of the 1913 figure. In the year 1915 the total output was a little more than half that of 1913, and for 1916-1917 there was only a slight improvement on the 1915 low level. For the succeeding years statistics are still incomplete, but it would appear that there was very little improvement in regard to the total quantity produced.

At the close of the period under consideration, namely, 31st December, 1919, the world was suffering from a serious shortage of phosphate resulting from the rapid falling off in production.

The United Kingdom did not suffer from the shortage to the same extent as did other European countries, as special efforts were made to secure supplies, but the European countries, more especially France and Germany, felt it very severely.

World's Production of Phosphates.

(long tons).

	1913.	1914.	1915.	1916.	1917.	1918.	1919.
Egypt	102,771	70,789	81,664	122,999	113,872	30,646	28,893
Canada	344	852	194	181	133	125	21
Christmas Island	149,956	93,703	23,731	44,209*	89,889*	53,370*	
Australia	5,950	6,783	5,714	7,455	8,626	11,918	9,017
New Zealand	11,000	10,743		7,600	5,050	5,000	4,000
Ocean Island	215,000	158,000	126,000	105,000	101,000	70,000	53,000
Nauru Island	133,000	72,000	92,000	97,000	98,000	83,000	60,000
Belgium	402,000	292,000	83,000	254,000	197,000	229,000	179,000
France	330,000	270,000		25,500			
Norway	745	738	1,870	2,200	1,803	4,489	
Russia	25,000	15,000		56,452			
Spain	3,491	8,178	8,934	13,884	27,696	42,607	24,633
Algeria*	431,552	349,432	222,261	382,956	231,051	199,284	238,294
Tunis	2,038,476	1,373,171	1,151,196	1,024,466	665,726	848,632	820,000
Dutch West Indies*	39,000	96,000	30,805	14,235	3,524		9,890
United States	3,152,208	2,649,174	1,935,341	2,169,149	2,851,886	2,284,245	1,851,549
Formosa	5,531	1,317	495	1,476			
Japan	18,737	37,644	56,788	112,965	119,673	189,181	120,893
Angaur Island	88,500	59,000*	29,500	29,500			
Makatea	80,737	71,753	70,571	38,654	31,741	39,000†	39,000†
New Caledonia		2,361	2,755	2,424	5,909		

* Exports.

† Estimated.

World's Production of Basic Slag and Superphosphates during 1913.

	Basic Slag. Quantity (long tons).	Superphosphates. Quantity (long tons).
Great Britain and Ireland	398,000	810,000
Australia	—	36,235
Austria-Hungary ...	50,000	390,000
Belgium	644,000	440,000
Denmark	—	89,000
France	718,000	1,890,000
Germany	2,214,000	1,789,500
Luxemburg	246,000	—
Italy	—	956,690
Netherlands	—	909,874*
Portugal	—	124,000
Russia	48,000	—
Spain	—	221,000
Sweden	18,059	181,298
United States	—	3,196,000

* Production during 1914.

Principal Phosphate Deposits of the World (After J. Fritsch).

(Reproduced from "The Manufacture of Chemical Manures," by permission of the publishers, Scott, Greenwood & Son, London.)

Geographical Distribution of Phosphate of Lime and Guano Deposits and their Chemical Composition.

Localities	Longitude of Greenwich (degrees)	Latitude (degrees)	Designation	Analysis (per cent.). Water.	Loss on Ignition.	Lime.	Lime not combined with P_2O_5.	Oxide of Iron.	Alumina.	Magnesia.	Phosphoric Acid.	Nitrogen.	Tribasic Phosphate of Lime.	Carbonate of Lime.	Calcium Fluoride.	Analyst.
A.—EUROPE.																
1. Sweden and Norway.	(Two small apatite deposits at Kragerö and Langesund.)															
2. Germany.	(Several small deposits of apatite, phosphorite, and coprolites.)															
3. Austria-Hungary.	(Four known deposits, one of which is bat guano.)															
4. Belgium.																
Liége	5·5 E.	50·6 N.	Phosphatic chalk.	0·93	2·83	40·64	—	2.39		0·79	27·25	—	59·49	7·04	—	Anglo Cont. G. Works.
Ciply	4 E.	50·5 N.	do.	1·52	—	45·45	19·18	1·75	1·11	—	22·17	—	48·44	—	—	A. Grimm.

Localities	Longitude of Greenwich (degrees)	Latitude (degrees)	Designation	Analysis (per cent.). Water.	Loss on Ignition.	Lime.	Lime not combined with P_2O_5.	Oxide of Iron.	Alumina.	Magnesia.	Phosphoric Acid.	Nitrogen.	Tribasic Phosphate of Lime.	Carbonate of Lime.	Calcium Fluoride.	Analyst.
A.—EUROPE—*cont.*																
5. FRANCE.																
Bellegarde-sur-Rhone	4·5 E.	43·7 N.	Coprolites	4·70	0·2	32·50	—	16·90	—	—	12·12	—	26·40	—	—	Dugléré.
Somme	2 E.	50 N.	Phosphorite	1·69	—	47·34	9·17	2·21		0·78	32.25	—	70·42	9·10	—	A. Grimm.
Lot	1·5 E.	44·5 N.	do.	4·27	—	50·10	—	2·96		0·26	37·07	—	80·92	3·43	—	Ulex.
Vaucluse	5 E.	44 N.	do.	2·45	—	26·57	—	3·30		0·33	19·90	—	43·44	0·84	—	E. Güsse-feld.
Ardennes	4·6 E.	50 N.	do.	—	—	—	—	4·6	2·3	—	18·04	—	36·43	10·13	3·0	Delattre.
Boulogne	1·5 E.	50·7 N.	Coprolites	0·84	3·14	33·06	—	2·89	3·09	0·58	21·06	—	45·97	—	—	
6. ITALY.																
Sardinia (Cagliari)	9 E.	39 N.	Bat guano	18·77	61·14	5·17	—	trace	trace	0·86	5·02	5·72	10·95	—	—	Pavesi and Rotond.
7. SPAIN.																
Cáceres	6·5 E.	39·5 N.	Phosphate	0·72	—	—	—	0·91	0·42	—	29·45	—	59·59	13·22	0·98	
Estremadura ...	6 W.	40 N.	Phosphorite	0·30	—	43·41	4·85	1·64		—	32·60	—	71·16	—	2·57 fluorine	Niederstedt and A. Grimm.
Logrosan	5·5 W.	39·4 N.	do.	2·40	—	—	—	2·22		—	38·95	—	85·03	10·35	—	De Luma.
Truxillo	6· W.	39·5 N.	do.	—	—	—	—	little	—	—	35·50	—	75·80	little	14·0	

8. Russia.																		
Podolia	27·5	E.	48·5	N.	Phosphorite (in balls).	—	—	—	—	—	—	—	34·0	—	74·23	6·92	—	
Kursk	36	E.	52	N.	Phosphorite	3·57	—	—	—	1·95	—	—	35·42	—	77·34	—	—	Schwackhöfer.
Woronesch	39	E.	52	N.	do.	—	—	—	—	—	—	—	13·74	—	30·0	24·0	—	Pieper.
9. Great Britain.	(There are a few deposits of coprolites which are no longer worked and one small deposit of mineral phosphate).																	
B.—NORTH AMERICA.																		
10. Canada.																		
Ontario	80	W.	45	N.	Apatite	0·08	—	—	—	—	—	—	39·98	—	86·61	4·47	7·22	W. R. Hutton.
Ottawa	75	W.	45	N.	do.	—	—	—	—	0·09	0·57	0·15	39·0	—	85·24	0·06	6·8	
11. United States.																		
New York	75·5	W.	44·4	N.	do.	0·2	—	51·48	—	1·07		—	37·0	—	79·59	2·32	6·42	H. Gilbert.
South Carolina ...	80	W.	33	N.	Phosphate	1·56	—	42·28	—	—	—	—	26·89	—	58·70	—	—	Völcker.
Charleston	80	W.	33	N.	do.	9·95	6·65	31·12	—	2·86	2·38	1·62	20·92	—	45·66	—	5·11 of fluor.	Ulex.
Port Royal	81	W.	32·5	N.	do.	0·58	1·01	37·79	—	2·82	1·12	0·5	23·67	—	51·67	9·18	—	
Tennessee	86	W.	35	N.	do.	0·80	—	50·60	7·20	3·32		—	36·69	—	80·09	—	—	H. Grimm.
Florida	80	W.	25·3	N.	do.	0·55	—	50·46	9·12	1·95		—	35·80	—	78·15	—	—	do.
Tallahasee	84·4	W.	30·5	N.	Phosphate (Hard-rock)	0·25	—	—	—	0·82	1·27	—	35·42	—	77·32	—	—	Pieper.
Barlow	82	W.	28	N.	Phosphate (Land-pebbles).	—	—	—	—	0·80	1·37	—	31·59	—	68·96	—	—	Völcker.
Peace River ...	82	W.	27·5	N.	Phosphate (River-pebbles).	1·05	—	—	—	0·52	1·64	—	23·08	—	61·30	—	—	Gilbert.

Localities	Longitude of Greenwich (degrees)	Latitude (degrees)	Designation	Analysis (per cent.). Water.	Loss on Ignition.	Lime.	Lime not combined with P_2O_5.	Oxide of Iron.	Alumina.	Magnesia.	Phosphoric Acid.	Nitrogen.	Tribasic Phosphate of Lime.	Carbonate of Lime.	Calcium Fluoride.	Analyst.
C.—WEST INDIES AND MEXICO.																
12. West Indies.																
Havana	82·5 W.	23 N.	Phosphate	11·90	—	—	—	2·88	—	—	34·08	—	74·40	—	—	Pieper.
Guanahani	74·3 W.	24 N.	Phospho-guano.	9·83	—	30·60	16·98	5·77		—	11·60	0·73	25·32	—	—	A. Grimm.
Vivorilla	—	—	do.	7·0	6·46	45·26	—	0·25		1·27	32·24	0·13	70·38	—	—	H. Gilbert.
13. Lesser Antilles.																
(*a*) Windward Islands.																
Avalo	81 W.	22 N.	Guano in crusts.	20·12	—	31·15	—	5·88	trace	0·44	24·36	0·45	53·18	—	—	A. Schlimper.
Navassa	75 W.	18·2 N.	Coralline phosphate.	2·7	—	37·6	—	14·8		0·6	33·5	0·11	73·13	5·6	—	Ulbricht.
Mona	67·5 W.	18·1 N.	Phospho-guano.	7·66	—	—	—	0·75		—	27·85	0·25	60·79	3·80	—	Weiss.
Sombrero	63·5 W.	19 N.	Guano in crusts.	9·06	—	36·17	—	2·42	6·89	0·36	34·41	—	74·55	—	—	Völcker.

St. Martin	63 W.	18 N.	Mineral phosphate.	5·04	—	47·69	—	1·21	2·99	0·38	24·14	—	52·70	32·27	—	Völcker.
Redonda	62 W.	17 N.	Phosphate of alumina.	23·23	—	—	—	36·38		—	36·95	—	80·66	—	—	do.
Alta Vela	71·5 W.	17·5 N.	do.	16·49	—	—	11·25	19·24		—	20·45	—	44·64	—	—	do
14. Lesser Antilles. (*b*) Leeward Islands.																			
Aruba	70 W.	12·5 N.	Mineral phosphate.	3·46	—	48·72	—	3·25		—	36·29	—	79·22	—	—	E. Güssefeld.
do.	—	—	do.	2·16	—	47·84	—	1·36	0·61	trace	33·82	—	71·65	10·66	—	A. Retter
Curaçao	69 W.	12 N.	do.	0·84	—	51·00	—	0·2	—	0·97	39·96	—	87·23	6·99	0·48 fluorine	E. Güssefeld.
Buenos Aires ...	68 W.	12 N.	do.	20·0	—	—	—	—	—	—	21·76	—	45·50	—	—	do.
Los Aves	67 W.	12 N.	Phospho-guano.	5·93	—	37·92	6·79	1·02		—	26·32	0·36	57·45	—	—	A. Grimm.
do.	—	—	do.	10·35	—	—	—	0·16	—	—	29·02	—	63·37	12·83	—	
do.	—	—	do.	14·90	—	—	—	0·35		—	22·40	—	48·90	7·05	—	
Los Roques... ...	66·5 W.	12 N.	Guano in crusts.	10·22	10·22	38·67	—	0·40	—	2·75	40·49	—	60.80	—	—	Taylor.
do.	—	—	Phosphate of iron.	—	—	—	—	40·5		—	37·0	—	80·77	1·0	—	Schucht.
Testigos	63 W.	12 N.	do.	12·17	12·17	0·37	—	13·30	—	0·57	17·41	—	38·0	—	—	Ure & Teschenmacher.
15. Mexico.																			
George	113 W.	31 N.	Phospho-guano.	—	—	—	—	1·50	—	—	37·71	—	82·33	—	—	E. Güssefeld.
Raza...	113 W.	29 N.	do.	4·08	—	35·28	—	1·14	—	1·18	39·70	0·40	86·66	—	—	Fr. Voigt.
Clipperton	108 W.	9 N.	do.	3·80	4.83	49·25	—	0·04		0·25	36·07	0·06	78·84	6·72	—	H. Gilbert.

Localities	Longitude of Greenwich (degrees)	Latitude (degrees)	Designation	Analysis (per cent.). Water.	Loss on Ignition.	Lime.	Lime not combined with P_2O_5.	Oxide of Iron.	Alumina.	Magnesia.	Phosphoric Acid.	Nitrogen.	Tribasic Phosphate of Lime.	Carbonate of Lime.	Calcium Fluoride.	Analyst.
D.—SOUTH AMERICA.																
17. BRAZIL.																
Fernando Naronha (Isle of Rata).	33 W.	4 S.	Phosphate	10·0	—	30·6	—	9·56	11·0	—	26·5	—	—	—	—	Schucht.
(*Note*: There are many guano deposits in Peru, Chile, Venezuela and Patagonia, details of which appear in "The Manufacture of Chemical Manures" by J. Fritsch—London: Scott, Greenwood & Son.)																
E.—PACIFIC OCEAN.	Many of the Oceanic Islands, notably the Phœnix and Baker Group, have extensive deposits of Phospho-guano.															
23.—GILBERT GROUP.																
Ocean Island ...	169 E.	1·5 S.	Phosphate	1·01	2·7	49·5	3·19	0·42	—		38·73	—	84·65	4·91	1·0	V. Grueber.
F.—AUSTRALIA AND AUSTRALIAN ISLES.	There is a deposit of Phospho-guano at Shark's Bay on the mainland of Australia, and considerable deposits of a similar character occur on many of the Australian Islands.															

G.—ASIA.																	
27. PALESTINE.																	
Country East of Jordan.	35·5	E.	32	N.	Phosphorite.	—	—	—	—	0·64	0·48	traces	38·24	—	83·68	—	9·8	Elschner.
29. MALAY ARCHIPELAGO.																	
Christmas Island ...	105·5	E.	10·5	S.	Phosphate.	3·05	—	—	—	0·71	1·22	0·26	39·18	—	83·53	4·82	3·44	H. Gilbert.
H.—AFRICA.																	
30. NORTH AFRICA.																	
Algeria	3	E.	37	N.	Mineral phosphate.	2·39	—	50·10	14·09	0·53		—	30.44	—	66·45	—	—	A. Grimm.
Tebessa	8	E.	35·5	N.	do.	1·97	—	50·30	—	0·55		0·50	28·16	—	61·47	20·19	—	A. Retter.
Toqueville	8	E.	36	N.	do.	0·77	—	—	—	0·98		0·81	26·32	—	57·46	22·80	—	do.
Tunis	10	E.	37	N.	do.	5·95		45·35	—	0·81	0·62	0·6	27·25	—	59·48	11·52	—	Schucht.
Sfax	10·5	E.	34·5	N.	do.	—	—	—	—	1·2	0·6	—	27·2	—	59·0	14·0	—	?
Gafsa	9	E.	45·4	N.	Phosphate.	2·6	2.99	45·12	—	1·68		0·5	27·23	—	59·44	11·95	—	Schucht.
Egypt	29	E.	31	N.	Bat guano.	17·19	29·50	—	2·76	—	—	—	—	11·81	—	—	—	Völcker.
31. SOUTH AFRICA.	There are four known deposits of guano and phospho-guano, but they are very low in tri-calcium phosphate.																	

PRICES.

In the year 1913 prices of phosphate had probably reached their lowest point, supply at that period having attained the maximum and having out-stripped the demand. An adequate representation of the prices ruling is exceedingly difficult, owing to the consideration that sales of phosphate-rock are made on the basis of percentage content of tri-calcium phosphate. In most of the published statistics of value only the average price obtained is quoted.

In regard to land-pebble phosphate for example, which varies from 66 to 79 per cent. tri-calcium phosphate, prices for the higher grade in 1919 were approximately six dollars per ton in excess of the prices ruling for the 66 per cent. grade. It will, therefore, be clear that the average price is no accurate guide to the market price obtaining for any particular grade, seeing that the average value would depend on the quantity of each grade mined during any particular period.

In the year 1913 the value of the standard 70 per cent. grade of land-pebble was aproximately $3.60 per ton, or, at the rate of exchange then ruling, 15*s.* per ton. By the end of 1919 this price had risen to $7.35 per ton, or almost exactly double the price obtaining in 1913.

In the intervening period prices fluctuated considerably. At the outbreak of the war exports of land-pebble to foreign countries fell away rapidly, and prices barely maintained the 1913 level. Owing to the demands which the belligerent countries made upon America for agricultural produce, the exportable surplus of land-pebble was gradually absorbed, and prices tended to rise, but by 1917 the advance was only about one dollar per ton over the 1913 level. After the Armistice, famine conditions obtained in the phosphate market, and, consequently, prices rose very rapidly, but, all things considered, the advance in the value of phosphate was not so great as in the case of many other commodities.

It is thought that a brief reference to the course of prices of Tunis phosphate will, together with the above remarks as to land-pebble, form a sufficient indication of the effects of the war on the phosphate market.

With Tunisian phosphate, as with land-pebble, prices vary with the quality of the rock. The price of the most popular grade, 58 to 63 per cent., had reached its lowest point in 1911, and while there was very little actual difference between prices obtaining in 1911 and 1913, the tendency was for the price to rise. The 1913 value of this grade may be taken at about 15*s.* 6*d.* per ton, the 63 to 68 per cent. grade being approximately 22*s.* 6*d.* per ton.

In Tunis, as in America, the first effects of war conditions were to weaken prices slightly, but in this area labour was very rapidly withdrawn from the phosphate mines to fill the fighting ranks, and production fell so speedily that the value of the phosphate commenced to rise at a very much earlier date than in the United States.

By 1916 the price of the 58 to 63 per cent. grade had risen to 25*s*. per ton, with a proportionate increase in the price of the higher grade, and to the end of the war prices rose steadily, if slowly. Immediately after the Armistice there was a very heavy demand for Tunisian phosphate, but owing to the labour position there was very little improvement in the output during the year 1919. In consequence prices were very much inflated and quotations varied from 37*s*. to as much as 49*s*. 6*d*. per ton for the lower grade.

Prices of Egyptian phosphate rose to an even higher point than those of Tunis, but the Pacific Islands phosphate did not show such a marked advance in price, owing to the fact that the world's principal consumers are so far removed from the source of production, lack of shipping facilities restricting the demand to markets near at hand.

THE MANUFACTURE OF SUPERPHOSPHATES.

The initiation of superphosphate manufacture from mineral phosphate-rock is ascribed to J. B. Lawes, an English agriculturist. It is believed that prior to his experiments a method of acidulating ground bones in order to obtain a form of soluble phosphate was practised, but it is generally admitted that Lawes was the first chemist to use mineral phosphates for the manufacture of superphosphates.

Lawes took out patents in England, in 1842, covering the acidulation of bones and phosphate-rock.

The first superphosphate is said to have been made from Cambridge coprolite by Lawes in 1845, and there can be no doubt that this discovery turned the attention of the world to the discovery of mineral phosphate deposits.

Amongst the earliest of these discoveries were the Somme deposits in France and the South Carolina and Florida deposits in the United States.

In the earliest processes of superphosphate manufacture, sulphuric acid was introduced into a lead-lined tank, the phosphate-rock being poured into the tank and stirred with hoes or rakes until reaction was complete, after which it was removed from the tank and spread out to dry.

The phosphate-rock was originally ground in a stone mill, and, in fact, stone mills are still used in many superphosphate factories; but in a large number of cases these mills have been replaced by ball mills or patent grinding mills of a similar nature.

The usual mixture in to-day's product is approximately 105 parts of sulphuric acid (115° Tw. or 66·53 per cent. H_2SO_4) with 100 parts of ground phosphate-rock. These are introduced together into a mixing chamber, where they are mechanically agitated until the reaction is complete. The loss in weight in manufacture is from 10 to 12½ per cent.

EXPERIMENTAL WORK.

There have been many attempts to discover a method of rendering the phosphate content of rock-phosphate soluble by other means than dissolving with acid, but so far no really satisfactory process has been evolved.

Many experiments have been conducted with the object of—

(1) fortifying low-grade phosphates,
(2) freeing them from ferric oxide and alumina,
(3) increasing their solubility.

The chief patents taken out for this purpose are given by J. Fritsch in the " Manufacture of Chemical Manures " (London : Scott, Greenwood and Son), from which the following is abstracted by permission of the publishers :—

1. *Dumonceau and Nicolas* (French Patents Nos. 201,427, and 201,461) propose to fortify low-grade phosphates, consisting of phosphate of lime and carbonate of lime, by the use of sulphur. The principle of the two methods is as follows :—Phosphatic chalk is calcined so as to produce a mixture of phosphate of lime and quicklime, which is mixed with water and sulphur in iron pans. The insoluble phosphate of lime is separated from the soluble sulphides formed. The strength is thus fortified 20 to 30 per cent.

2. *Simpson* replaces sulphur by sulphuretted hydrogen (German patent 58,925), and, after calcination of the raw phosphates, injects it into water, holding the phosphates in suspension.

3. *Brochon* (French patent 215,577) extracts phosphates rich in carbonate of lime by means of carbonic acid under pressure after crushing and stirring with water.

4. *Winsinger,* to prepare bi-calcium phosphate free from oxide of iron, completely soluble in citrate of ammonia (German patent No. 51,739), extracts all the phosphoric acid of the phosphate of lime by sulphuric acid, converts half the solution into mono-calcium phosphate, by the addition of carbonate of lime and milk of lime, which precipitate the iron ; he adds this precipitate to the other half, and obtains by the addition of sodium sulphate, sodium carbonate and quicklime, phosphate of lime insoluble in water free from oxide of iron, which he finally adds to the solution of mono-calcium phosphate.

5. *O. Iahne* (German patent 57,295) prepares phosphate of lime free from oxide of iron, alumina, and silica, by acting on phosphates rich in oxide of iron and alumina with sodium bisulphate. The raw phosphates (coprolites, etc.), in this case carbonate and phosphate of lime, treated with an aqueous solution of sodium bisulphate, dissolve, whilst the silica, iron, and alumina compounds remain insoluble, and may be separated by filtration along with the gypsum.

6. In making superphosphates, *Martin* proposes to use the acid sulphate from the manufacture of nitric acid. The acid sulphate from the cylinders is dissolved in water, so as to produce

a solution of 45° to 50° Baumé. The precipitate consists of bisulphate, which it is easy to convert into sulphate by re-crystallization, whilst the strongly acid solution is used to dissolve raw phosphates. All the phosphoric acid is dissolved, and the resultant superphosphates have less tendency to retrograde than those made with sulphuric acid of 50° to 53° Baumé.

7. *Thonnar and Huxton's* Belgian patent No. 96,109, and Rolland's Belgian patent 196,190, to eliminate the oxides of iron and alumina, may also be mentioned.

8. *Schucht* proposed to make superphosphates from ferruginous phosphate thus: As soluble ferric oxide induces retrogradation of the phosphoric acid in superphosphates, whilst the ferrous oxide is inactive, and as sulphate of ammonia possesses the property of forming with a ferrous salt double salts very stable in air, Schucht, on such data, proposed to dissolve phosphates in presence of sulphate of ammonia, then to effect the reduction and so obtain very stable superphosphates of ammonia. With this end in view, the finely ground superphosphates are mixed with sulphate of ammonia. One part Fe_2O_3 requires 1·75 parts of that salt to form the double salt $FeSO_4 + (NH_4)_2 SO_4 + 6H_2O$. Reduction can only be effected by weak sulphurous acid which is injected under pressure into the diluted mixture of superphosphate heated to 80° to 100°C.

9. *Carr's* process, dealing with phosphates rich in oxides of iron and alumina is analogous. It consists in calcining the phosphate, grinding it fine and then mixing 1,000 parts with 400 parts of sulphate of ammonia dissolved in 400 c.c. of hot water, to which is then added 800 parts of sulphuric acid of 53° Baumé. A violent reaction ensues, the mass intumesces and heats to 110° C. After an hour it solidifies and is easily ground; it contains 18 per cent. of phosphoric acid, two-thirds of which is soluble in water.

Author's Note.—It is evident that such generalizations are futile. The data given can only have been applicable to the particular phosphate to which Carr applied it. All phosphates rich in oxides of iron and alumina would not respond to such treatment so as to yield the above results.

10. *Glaser* proposes to manufacture precipitated phosphates from insoluble phosphates of alumina, by treating the latter with a cold alkaline solution or with a hot concentrated solution of alkaline carbonate. In this operation the phosphate of alumina is dissolved. In using the alkaline solution, the liquid separated from the residues is treated with carbonic acid. If a hot solution of alkaline carbonate be used, it is cooled, and the dissolved phosphate of alumina is precipitated.

11. *Petermann*, of Gembloux, recommends treating the raw phosphate at a high temperature to convert the phosphoric acid into a very soluble form. Bazin has based a British patent No. 15,237 on this principle. He heats phosphates in retorts to a temperature of 1,300° to 1,500° C.

12. *Hodgkins* (American patent No. 423,320, 1890) mixes the phosphate in fine powder, with quicklime, which he then slakes. But it is not apparent how such treatment can render phosphates more soluble. Besides, no field experiments appear to have been made to test the value of the resultant manure.

Manufacture of Precipitated Phosphate by Electrolysis.—A new method of manufacture, based on electrolysis, has been invented by Prof. W. Palmer, of Stockholm. It consists in converting the raw phosphate by the wet way into a readily assimilable form, at an ordinary or slightly elevated temperature. The raw material is ground apatite, which need not be finely ground. In an apparatus, specially constructed for the purpose, a solution of chlorate or perchlorate of soda is electrolysed; this disengages free chloric acid, sometimes even perchloric acid, in the " anode " cell. The acid " anode " liquid is made to react on the raw phosphate in a battery of wooden cases, fitted with perforated bottoms, so that the solvent first comes in contact with almost exhausted apatite. The alkaline liquid from the " cathode " is added to the saturated solution, in special precipitation vats, taking care to stir, until a slightly acid reaction ensues. There is thus formed a crystalline precipitate of acid phosphate of lime. It is freed as completely as possible from the mother liquor by filtration and washing, which is greatly facilitated by the physical nature of the phosphates. The yield is very satisfactory, because only about 1 per cent. of the phosphate in the raw material remains in the solution. The latter, which contains a third of the amount of lime originally eliminated from the apatite, is mixed with the residual alkaline cathode liquid, when the greater part of the lime is precipitated as hydrate; finally, a current of carbonic acid gas is injected. After precipitating the lime the solution is withdrawn and run into the electrolyser. The electrolyte is thus continuously regenerated. The product so obtained generally contains 36 to 38 per cent. of total phosphoric acid (the formula $CaHPO_4 + 2H_2O$ requiring 46·07 per cent. of P_2O_5). About 95 per cent. of the phosphoric acid in this product is soluble in Petermann's solution of ammoniacal citrate of ammonia.

Other alternative methods have all been along the lines of the investigations of Dr. Marloth, who mixed 100 parts of finely ground rock with 40 parts of ground limestone, 20 of common salt and 10 parts of dried sulphate of ammonia. The mixture was briquetted and calcined at red heat in a kiln, after which it was ground to pass a mesh of 100 to the linear inch.

A somewhat similar process was evolved in Italy, the resultant product being called " tetra-phosphate." The Italian process was developed commercially and used to a limited extent during the war period.

The advantage of manufacturing the mineral phosphate into superphosphate by admixture of sulphuric acid is that the

phosphate of the rock is rendered soluble in water and this makes it available for crops immediately it is applied to the soil. The extent to which the original phosphate content of the rock is rendered water-soluble depends upon the percentage of ferric oxide and alumina in the mineral used, hence for superphosphate manufacture a mineral which contains more than 4 per cent. of iron oxide and alumina is seldom, if ever, employed. The action of the metallic oxides in the process of dissolving is not very clearly understood, and it will suffice to say that they neutralize a percentage of the phosphate, which passes over into the finished superphosphate as not soluble in either water or a 2 per cent. solution of citric acid. Another injurious effect of iron oxide and alumina is that they tend to cause reversion from water-soluble to citrate-soluble in the finished superphosphate, due to the interaction of the mono-calcium phosphate and the tri-calcium phosphate, leading to the formation of di-calcium phosphate, or to the formation of ferric and aluminium phosphates by the action of the mono-calcium phosphate upon the iron and aluminium sulphates.

In the latter case sulphuric acid is again set free and this in turn may possibly act upon some of the tri-calcium phosphate.

BRITISH EMPIRE.

United Kingdom.*

Formerly phosphate-rock was obtained at many places in England, more particularly from the Cambridge Upper Greensand, where the productive bed consists of dark-brown or black nodules of phosphate of lime and is from 8 to 12 inches in thickness, and from a bed of phosphatic nodules 12 to 18 inches in thickness in Suffolk.

Both these deposits produced a considerable output of rock, but the methods employed and the conditions under which mining operations were carried out rendered the cost of production rather high. Following upon the discovery and exploitation of the great American and African deposits of phosphate-rock, phosphate-mining in England ceased to be profitable, as the amount of iron present caused the phosphate to revert to the insoluble form, and very little phosphate-rock has been mined in England in recent years.

The output of superphosphate in the United Kingdom had gradually grown until at the opening of the war there were upwards of 80 factories engaged in the industry, the total output being approximately 800,000 tons. The development of the United States and African deposits of phosphate-rock, noted above, and the cessation of the working of the English deposits, rendered

* Memoirs of the Geol. Surv. Special Reports on the Mineral Resources of Great Britain, 1917, **5**, 15–24. Annual Statements of the Trade of the United Kingdom.

the United Kingdom manufacturers dependent upon foreign sources for their supply of raw phosphate-rock, consequently all the factories are to be found either at or in the vicinity of the principal ports. The geographical distribution of the phosphate works is such that the supplies of superphosphate do not have to be forwarded for any considerable distance. The principal centres of superphosphate manufacture are as follows :—

England.—Mersey, London, Humber, Bristol Channel, Ipswich, Lynn, Plymouth, Newcastle.
Scotland.—Glasgow, Leith and district, Aberdeen.
Ireland.—Dublin, Belfast, Cork.

For the first two years of the war the superphosphate trade was left to obtain its own supplies of raw materials, and on account of the enormous demand for sulphuric acid for the manufacture of munitions it was found that there was a very considerable reduction in the superphosphate output.

To such a degree had the manufacture fallen that the production for the year 1917 was rather less than half that of 1913, and this occurred at a time when strenuous efforts were being made to combat the submarine menace to our food supply by increasing by every means possible the production of food in the United Kingdom.

During the summer of 1917 the position had become very serious, and the Government decided to take over the whole of the superphosphate industry and to import and provide to the manufacturers of superphosphate the whole of the raw materials which they required.

Under an order issued in accordance with the Defence of the Realm Regulations the Minister of Munitions took over the whole of the stocks of phosphate-rock and superphosphate in the country. Arrangements were made for an adequate supply of acid to be provided for the manufacture of superphosphate, and shipping was also obtained for phosphate-rock. The result of these efforts is very plainly apparent in the figures of imports which are appended to this section.

The imports of phosphate in 1918 amounted to 464,872 tons, as against 276,617 tons in the year 1917. The superphosphate production in the year 1918 was approximately 800,000 tons, as compared with 460,000 tons in 1917. It has already been mentioned that the prices of raw phosphate up to the years 1917-18 had not risen very considerably, but, on the other hand, the submarine menace was then at its height and consequently the cost of bringing raw phosphate to this country had risen to a very alarming figure.

Although the shipping was, in fact, provided by the State, at the same time it was considered necessary to add to the actual cost of the freight a proportion of the very heavy expenses which fell on the State by reason of the frequent total loss of steamers and cargoes. It was not possible, however, for the whole of these expenses to be passed on to the price of superphosphate as this

would have rendered the cost per ton of superphosphate to the farmer prohibitive and would thus have tended to discourage the use of fertilizers, which were essential for intensive food production. The State, therefore, fixed a reasonable price for superphosphate, and bore a proportion of the cost as a loss in the interest of agriculture.

During the year 1918 the demands on shipping for the moving of American troops to the theatre of war were such that for some two months it appeared as though it would not be possible to provide sufficient ships for the transport of phosphates. It was accordingly decided to re-open the Cambridge workings, and some thousands of tons of the so-called coprolites from the Trumpington bed were extracted. This coprolite is, however, of lower grade than that usually used for superphosphate manufacture, and consequently it had to be blended with the higher-grade rocks which were imported from outside sources.

Later, however, with the change in the fortunes of war during the summer of 1918, the strain on British shipping was to a certain extent relieved. Consequently the State again returned to foreign sources of supply for raw phosphate, and the Trumpington workings were closed down.

It will be seen by reference to the statistics attached that in the normal pre-war year of 1913 a total of 539,016 tons of rock-phosphate and superphosphate were imported into the United Kingdom. The official statistics from which these figures are taken do not distinguish between the two materials, but so far as can be estimated from the sources of supply, about 460,000 tons of this quantity would be raw phosphate, and the balance, approximately 79,000 tons, would be in the form of superphosphate. The demand in the United Kingdom was mainly for superphosphate containing 26 to 30 per cent. of tri-calcium phosphate, which is manufactured from the grades of phosphate imported from Tunis and Algeria.

Some proportion of the high-grade rock-phosphate imported from the United States and the Pacific Islands was, however, used for the manufacture of the lower-grade superphosphate, the usual practice being to blend with the high-grade rock a proportion of the low-grade phosphates obtained from Belgium and France. It will be observed from the statistics which follow that, during the war period, an increasingly large proportion of the supplies for the United Kingdom was taken from Algeria and Tunis, the imports from the United States falling from 177,330 tons in 1913 to 13,361 tons in 1918. The principal reason for this variation is to be found in the shortage of shipping previously referred to. It will be obvious that in such circumstances it became vitally necessary to secure the major portion of the supplies of phosphate-rock from the nearest possible source.

It is of interest to note that in 1919, when the effects of the war were beginning to pass away, the imports from the United

States rose to 47,800 tons, and at the same time the imports from Algeria and Tunis fell from 446,500 tons to 292,400 tons.

In the pre-war period the United Kingdom was one of the principal superphosphate manufacturing countries. America produced the largest quantity of superphosphate, the second and third places being occupied by France and Germany, with a production of approximately 1,800,000 tons each, the United Kingdom following with a production of about 800,000 tons.

Imports of Superphosphate of Lime and Rock-Phosphate into the United Kingdom.

From	Quantity (long tons)						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
Egypt	15	300	10,380	11,111	9,412	400	730
British Pacific Possessions	5,744	24,807	2,426	—	—	—	—
Other British Possessions ...	2	—	—	36	—	3,941	—
Total from British Possessions	5,761	25,107	12,806	11,147	9,412	4,341	730
Belgium	63,969	62,912	—	600	—	—	3,634
France...	10,166	6,989	300	—	—	—	—
Germany	14,168	26,248	—	30	—	—	—
Netherlands	24,347	21,251	250	502	734	666	208
Algeria	44,996	40,380	73,492	81,876	70,812	32,871	48,496
Tunis	189,555	181,107	195,977	174,640	144,443	413,633	243,883
United States	177,330	177,792	81,484	61,828	44,982	13,361	47,807
Dutch West India Islands...	4,476	3,830	10,330	2,777	1,930	—	—
French Pacific Possessions	2,633	7,415	—	—	—	—	—
German Pacific Possessions	—	9,201	—	—	—	—	—
Other Foreign Countries ...	1,615	10	—	21	4,304	—	11,000
Total from Foreign Countries	533,255	537,135	361,833	322,274	267,205	460,531	355,028
TOTAL	539,016	562,242	374,639	333,421	276,617	464,872	355,758
	Value (£).						
Egypt	30	363	18,915	34,385	46,340	9,505	7,250
British Pacific Possessions	15,283	55,975	3,033	—	—	—	—
Other British Possessions ...	5	—	—	210	—	16,720	—
Total from British Possessions	15,318	56,338	21,948	34,595	46,340	26,225	7,250
Belgium	108,608	129,167	—	1,200	—	—	12,089
France...	12,920	11,713	2,247	—	—	—	—
Germany	37,990	72,181	—	60	—	—	—
Netherlands	50,565	50,261	888	4,997	7,335	18,449	5,770
Algeria	66,598	61,320	156,210	241,016	317,131	138,850	188,601
Tunis	249,732	241,322	305,967	425,246	584,707	1,692,854	859,720
United States	314,246	304,434	170,052	116,489	182,155	72,165	184,496
Dutch West India Islands	8,377	7,610	47,437	15,185	14,445	—	—
French Pacific Possessions	6,582	15,851	—	—	—	—	—
German Pacific Possessions	—	20,074	—	—	—	—	—
Other Foreign Countries ...	3,230	66	—	34	20,444	—	84,300
Total from Foreign Countries	858,848	913,999	682,801	804,227	1,126,217	1,922,318	1,334,976
TOTAL	874,166	970,337	704,749	838,822	1,172,557	1,948,543	1,342,226

Imports of Guano into the United Kingdom.

From	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
Falkland Islands ...	1,823	3,620	4,981	8,047	1,299	—	—
Seychelles	2,491	8,741	—	—	—	—	—
Other British Possessions	2,966	1,975	469	81	—	—	101
Total from British Possessions	7,280	14,336	5,450	8,128	1,299	—	101
Belgium	401	1,580	—	—	—	—	—
Argentina	390	—	—	—	—	—	—
Peru	15,187	17,083	16,479	9,665	—	—	—
Uruguay	793	190	—	915	1,034	—	—
Other Foreign Countries	1,497	6,096	4,791	2,937	268	—	—
Total from Foreign Countries	18,268	24,949	21,270	13,517	1,302	—	—
TOTAL	25,548	39,285	26,720	21,645	2,601	—	101
	Value (£).						
Falkland Islands ...	12,300	25,791	34,733	76,826	13,291	—	—
Seychelles	7,500	27,474	—	—	—	—	—
Other British Possessions	12,288	14,436	3,151	837	—	—	1,250
Total from British Possessions	32,088	67,701	37,884	77,663	13,291	—	1,250
Belgium	3,159	7,921	—	—	—	—	—
Argentina	2,269	—	—	—	—	—	—
Peru	97,502	126,130	105,164	105,001	—	—	—
Uruguay	4,910	905	—	5,098	11,374	—	—
Other Foreign Countries	9,261	29,429	38,957	30,952	3,010	—	—
Total from Foreign Countries	117,101	164,385	144,121	141,051	14,384	—	—
TOTAL	149,189	232,086	182,005	218,714	27,675	—	1,250

Exports of Superphosphates from the United Kingdom (Domestic Produce).

To	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
Channel Islands ...	2,743	2,006	1,817	2,221	2,433	2,544	1,013
Cape of Good Hope ...	1,013	5,635	20,253	8,243	700	—	569
Natal	1,360	2,493	6,419	2,494	71	—	40
Mauritius and Dependencies	776	1,336	1,907	1,124	—	—	198
Australia	7,321	5,934	1,016	—	—	—	—
New Zealand	12,522	13,919	6,096	98	—	—	—
Other British Possessions	1,367	2,709	1,043	121	—	3	445
Total to British Possessions	27,102	34,032	38,551	14,301	3,204	2,547	2,265
Denmark (including Faröe Islands)	12,040	15,236	24,650	—	—	—	4
France	4,200	5,423	1,376	—	—	—	—
Portugal	1,783	2,675	1	—	—	—	—
Russia	4,801	1,878	—	—	—	—	—
Spain	6,585	2,541	455	—	—	—	90
Canary Islands	4,105	2,508	1,792	67	—	—	1,456
Other Foreign Countries	2,864	1,758	1,854	—	—	—	211
Total to Foreign Countries	36,378	32,019	30,128	67	—	—	1,761
TOTAL	63,480	66,051	68,679	14,368	3,204	2,547	4,026
	Value (£).						
Channel Islands ...	8,588	7,387	5,994	9,869	15,908	16,411	6,799
Cape of Good Hope ...	2,764	16,397	71,688	40,763	3,853	—	6,090
Natal	5,109	9,671	29,943	14,549	359	—	420
Mauritius and Dependencies	2,717	5,003	7,863	7,470	—	—	2,357
Australia	16,347	12,631	2,390	—	—	—	—
New Zealand	34,531	38,302	16,999	325	—	—	—
Other British Possessions	4,010	8,010	5,751	753	—	10	5,157
Total to British Possessions	74,066	97,401	140,628	73,729	20,120	16,421	20,823
Denmark (including Faröe Islands)	30,635	38,372	66,025	—	—	—	60
France	9,474	12,105	3,926	—	—	—	—
Portugal	4,033	5,724	10	—	—	—	—
Russia	10,871	3,804	—	—	—	—	—
Spain	16,064	6,153	1,155	—	—	—	945
Canary Islands	11,864	7,012	6,789	324	—	—	14,195
Other Foreign Countries	9,307	4,878	5,584	—	—	—	2,558
Total to Foreign Countries	92,248	78,048	83,489	324	—	—	17,758
TOTAL	166,314	175,449	224,117	74,053	20,120	16,421	38,581

Exports of Phosphate of Lime and Rock-Phosphate from the United Kingdom (Colonial and Foreign Produce).

To	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
New Zealand	11,561	29,640	—	—	—	—	—
Other British Possessions	50	400	200	10	—	—	—
Total to British Possessions	11,611	30,040	200	10	—	—	—
Denmark (including Faröe Islands)	—	6,970	—	—	—	—	—
Sweden	—	21,995	—	2,370	—	—	—
Other Foreign Countries	11	2,737	—	—	—	—	—
Total to Foreign Countries	11	31,702	—	2,370	—	—	—
TOTAL	11,622	61,742	200	2,380	—	—	—
	Value (£).						
New Zealand	31,138	79,845	—	—	—	—	—
Other British Possessions	64	2,000	565	38	—	—	—
Total to British Possessions	31,202	81,845	565	38	—	—	—
Denmark (including Faröe Islands)	—	14,229	—	—	—	—	—
Sweden	—	47,966	—	11,850	—	—	—
Other Foreign Countries	22	4,227	—	—	—	—	—
Total to Foreign Countries	22	66,422	—	11,850	—	—	—
TOTAL	31,224	148,267	565	11,888	—	—	—

Exports of Guano from the United Kingdom (Colonial and Foreign Produce).

To	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919
British Guiana	450	150	821	330	130	—	—
Mauritius and Dependencies	357	—	—	—	—	—	—
Other British Possessions	265	74	265	168	16	—	—
Total to British Possessions	1,072	224	1,086	498	146	—	—
Belgium	468	1,060	—	—	—	—	—
Germany...	788	—	—	—	—	—	—
Norway	—	—	2,030	—	—	—	—
United States	962	2,370	343	—	—	—	—
Other Foreign Countries	25	158	301	516	204	—	—
Total to Foreign Countries	2,243	3,588	2,674	516	204	—	—
TOTAL	3,315	3,812	3,760	1,014	350	—	—
	Value (£).						
British Guiana	4,450	1,750	10,707	4,414	2,192	—	—
Mauritius and Dependencies	2,622	—	—	—	—	—	—
Other British Possessions	1,320	598	3,079	2,220	238	—	—
Total to British Possessions	8,392	2,348	13,786	6,634	2,430	—	—
Belgium	4,964	6,348	—	—	—	—	—
Germany...	5,544	—	—	—	—	—	—
Norway	—	—	16,428	—	—	—	—
United States	5,885	17,732	2,385	—	—	—	—
Other Foreign Countries	238	1,646	2,304	5,719	2,225	—	5
Total to Foreign Countries	16,631	25,726	21,117	5,719	2,225	—	5
TOTAL	25,023	28,074	34,903	12,353	4,655	—	5

Egypt.*

The known deposits of phosphate of lime in Egypt occur in the Cretaceous system, more particularly in the upper portion, under conditions closely resembling those in Algeria and Tunis.

* The Phosphate Deposits of Egypt, by J. Ball ; Surv. Dept. Paper No. 30, 1913.

Topography and Geology of the Phosphate District of Safâga (Eastern Desert of Egypt), by J. Ball ; Surv. Dept. Paper No. 29, 1913.

Annuaire Statistique de l'Égypte.

They consist largely of low-grade phosphorite, averaging only about 45 per cent. tri-calcium phosphate, and are therefore unsuitable for export; but high-grade rock containing up to 75 per cent. of tri-calcium phosphate is being mined in increasing quantity from beds outcropping at the Um el Huetat mine, situated about 18 miles south of Port Safâga on the Red Sea. This mine is connected by railway with Port Safâga, where the rock is loaded into steamers and exported chiefly to Japan and elsewhere in the East.

A little to the north-west of Qosir, on the south and west plateau of the Duwi range in the Nakheil district, an occurrence of high-grade rock is reported. Phosphate-bearing beds, from 18 inches to 2 feet in thickness, occur also on the eastern slopes of the Red Sea hills. These exposures cover an area from 150 to 300 feet in width and about 4 miles in length.

In 1913 an expedition examined the Red Sea phosphate beds, but, with the exception of the extensive Safâga deposit, the tonnage of high-grade phosphate-rock available was found to be too limited to warrant the acquisition of any property.

Extensive beds of phosphate of lime occur in the Nile Valley, notably in the Sibaia district, on both sides of the river. The bone beds outcrop at a point about 11 miles south of Esna, where three thin beds occur. Analyses of samples from these beds showed the material to be too poor in phosphoric acid to warrant exploitation.

At Sibaia the deposits consist of four beds of phosphate of lime which have a total thickness of about 6 feet. Farther to the north, near the village of Qift, there is an extensive bone bed about 3 feet in thickness which covers the larger part of the Gebel el Qurn plateau, the area of the deposit being about 2,500 acres. The distance to Qift railway station is from 6 to 12 miles. Chemical examination has shown that these beds have undergone silicification, with a consequent lowering of the percentage of phosphoric anhydride to the extent of about 7 per cent. in the upper layer of the bed, but there remains an average thickness of about 18 inches of unaltered bone bed. Throughout the whole of this area there is very little overburden above the bone beds, the thickness of cover rarely exceeding 9 feet of loose rubble, while in places the bone beds form the surface.

An Italian company has obtained large concessions in this district, and also on an extension of these beds on the west bank of the Nile. The rock quarried from the Gebel el Qurn deposit is transported by aerial ropeway to the Nile, and thence by boat to Alexandria, where it is shipped to Europe. Analyses of the phosphate-rock from these districts of the Nile Valley indicate that an average of over 45 per cent tri-calcium phosphate may be expected.

Phosphatic beds occur also throughout the Dakhla oasis, the total area of outcrop in this region being about 19 square miles.

The Egyptian phosphate beds, with the exception of parts of the Sibaia and Gebel el Qurn deposits and those at Safâga and Dakhla, are mostly too poor in quality to admit of profitable mining for export. There should, however, be a large demand for this material for domestic consumption when the Fellahin and small farmers of the Nile Valley have learned the value of phosphate of lime as a fertilizer. So far, the domestic demand for the native insoluble phosphate, of which Egypt possesses a practically inexhaustible supply, has been small.

Egyptian Production and Exports of Phosphates.

Year.	Production. Quantity (long tons).	Exports. Quantity (long tons).
1913	102,771	63,151
1914	70,789	85,181
1915	81,664	32,386
1916	122,999	20,196
1917	113,872	25,499
1918	30,646	9,196
1919	28,893	77,263

Details of the exports for 1918 and 1919 are as follows :—

	1918 (long tons).	1919 (long tons).
United Kingdom	395	1,022
Australia and New Zealand ...	—	9,839
Italy	—	31,594
Japan	3,031	20,998
Other Countries	5,770	13,810
Total	9,196	77,263

Union of South Africa.*

So far as is known at present, the only deposits of phosphate-rock of any considerable commercial importance in the Union of South Africa are the aluminous phosphates of Saldanha Bay, on the south-west coast of Cape Province.

The rocks of this district consist chiefly of granite and porphyry, which form a succession of isolated hills rising above an arid region of blown sand. The phosphates are found outcropping on the two hills lying north and south of the entrance to Saldanha Bay.

* Report on the Phosphates of Saldanha Bay, by A. L. Du Toit ; Union of South Africa Department of Mines and Industries Geol. Surv. Memoir., No. 10, 1917.

Annual Reports of the Government Mining Engineer of the Union of South Africa. Annual Statements of the Trade and Shipping of the Union of South Africa and of Southern and Northern Rhodesia.

At the northern locality known as Hoedjes Bay, the rock crops out in the sandy soil at the foot of the hill, and phosphate-rock has been observed extending to the top of the mountain, at an elevation of 364 feet. The depth of this sheet or surface covering is variable, and sufficient prospecting has not yet been done to allow of any estimate of the quantity being made. Where tested, the rock has been found to have a thickness of 4 to 15 feet.

Analyses of samples of the phosphates obtained at Hoedjes Bay show from 10 to 23 per cent. of phosphorus pentoxide, from 16 to 77 per cent. of silica, and from 7 to 37 per cent. of iron oxide and alumina.

At the southern locality known as Oude Post, the phosphates crop out on the flanks of Constable Hill at a general elevation of 150 feet, and continue to immediately below the bare granite summit, 616 feet above sea level. The material in the Oude Post deposits differs somewhat from that at Hoedjes Bay in carrying a considerable percentage of quartz; but the percentage of phosphoric acid is somewhat higher, varying from 14·8 per cent. to 32·63 per cent. These deposits have not been opened up, and the probable reserves have not been estimated, although they are stated to be large.

Throughout the Saldanha Bay deposits, there is very little phosphate of lime, the phosphoric acid being almost entirely combined with alumina and iron.

Before the war there was a small plant at Hoedjes Bay, consisting of a mill for grinding phosphate rock. A superphosphate plant was, however, in process of erection, and during the year 1919 an up-to-date plant was being erected at Somerset West, Cape Province. When this plant is finished, South Africa will be in a position to manufacture a considerable proportion of its requirements of phosphate fertilizer.

Other districts within the Union where phosphates are known to occur are Weenen, in Natal, where the deposits are of low grade, carrying only about 8 per cent. of phosphorus pentoxide, and Lulukop, in the Zoutpansberg district of the Transvaal. Lulukop is an isolated hill of very pure limestone which carries considerable quantities of apatite and magnetite. The apatite is reported to amount to about 10 per cent. of the rock in places. The deposit lies in a remote and unhealthy district, and it does not seem probable that any considerable supply will be obtainable from this source.

Phosphate deposits are known to occur at Cape Cross, north of Swakopmund, South-West Africa; in the Kuruman district, South Bechuanaland; in the Kenhardt Division of Cape Province; and on Bird Island, Algoa Bay. Sufficient development work has not yet been done in any of these localities to prove their economic value.

Value of Phosphates produced in Cape Province.

Year.	Value (£).
1916	1,305
1917	2,875
1918	6,639
1919*	—

* Operations were suspended during the year 1919.

*Imports of Raw Phosphates into the Union of South Africa.**

From	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ...	140	132	—	—	—	—	—
Egypt	—	—	—	—	—	4,514	5,600
South West Africa Protectorate	—	—	—	—	—	—	252
Total from British Possessions	140	132	—	—	—	4,514	5,852
Belgium	55	5	—	—	—	—	—
Germany...	485	200	—	—	—	—	—
Total from Foreign Countries	540	205	—	—	—	—	—
TOTAL	680	337	—	—	—	4,514	5,852
	Value (£).						
United Kingdom ...	446	739	—	—	—	—	—
Egypt	—	—	—	—	—	6,771	10,000
South West Africa Protectorate	—	—	—	—	—	—	1,974
Total from British Possessions	446	739	—	—	—	6,771	11,974
Belgium	126	12	—	—	—	—	—
Germany	1,133	433	—	—	—	—	—
Total from Foreign Countries	1,259	445	—	—	—	—	—
TOTAL	1,705	1,184	—	—	—	6,771	11,974

* In each of the years 1914 and 1918 phosphates to the value of £1 were imported from St. Helena.

Imports of Superphosphates into the Union of South Africa.

From	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ...	2,648	5,374	25,465	10,845	601	—	740
Australia	2	—	—	—	—	—	—
Total from British Possessions	2,650	5,374	25,465	10,845	601	—	740
Belgium	2,405	242	—	—	—	—	—
Germany	6,903	3,722	—	—	—	—	—
Holland	24,383	23,551	1,856	—	—	—	—
Portugal	—	—	200	—	—	—	—
Portuguese East Africa	278	—	—	—	—	—	—
United States	—	—	2,157	357	—	3,300	—
Argentina	—	—	—	—	—	88	—
Japan	—	—	600	6,673	5,612	2,675	—
Total from Foreign Countries	33,969	27,515	4,813	7,030	5,612	6,063	—
TOTAL	36,619	32,889	30,278	17,875	6,213	6,063	740
	Value (£).						
United Kingdom ...	7,731	18,080	94,102	59,424	3,521	—	7,792
Australia	4	—	—	—	—	—	—
Total from British Possessions	7,735	18,080	94,102	59,424	3,521	—	7,792
Belgium	5,619	1,002	—	—	—	—	—
Germany	19,514	9,300	—	—	—	—	—
Holland	61,432	59,721	5,527	—	—	—	—
Portugal	—	—	650	—	—	—	—
Portuguese East Africa	973	—	—	—	—	—	—
United States	—	—	7,838	1,766	3	28,854	—
Argentina	—	—	—	—	—	1,524	—
Japan	—	—	2,026	28,635	26,901	47,740	—
Total from Foreign Countries	87,538	70,023	16,041	30,401	26,904	78,118	—
TOTAL	95,273	88,103	110,143	89,825	30,425	78,118	7,792

Canada.*

Prior to the development of the United States phosphate deposits, Canada produced important quantities of phosphate-rock and exported considerable amounts to the United Kingdom. The material mined was wholly apatite, containing from 31·87 to 41·54 per cent. phosphoric acid.

* Economic Minerals and Mining Industries of Canada; Mines Branch, Dept. of Mines, Ottawa, Canada, 1914, p. 50. Investigation of a Reported Discovery of Phosphate in Alberta, by Hugh S. de Schmid; Canada Dept. Mines, 1916, Bull. No. 12. Annual Reports on the Mineral Production of Canada. Annual Reports on the Trade of Canada.

The importation of cheap phosphate-rock from the Unite States seriously affected the phosphate-mining industry in Canada and in recent years the only production of apatite in the Dominio has been an annual output of a few hundred tons obtained durin mica-mining operations on the extensive mica belt in Ottaw county, Quebec. Throughout the region extending from th Ottawa River on the south, northwards through the township of Buckingham, Templeton, Wakefield, Bowman and Hincks deposits of apatite occur abundantly over a width of 15 to 2 miles.

The deposits in the province of Ontario are less important tha those of Quebec. The mineral occurs as crystal aggregates in matrix of crystalline limestone. The area within which apatit is found extends southward from the Ottawa River to within few miles of the St. Lawrence, a distance of nearly 100 miles The average width of the belt is from 50 to 75 miles.

*Analyses of typical Quebec Apatites.**

	McLelland Mine, Hull.	Scott Mine, Hull.	Rainville Mine, Templeton.	High Falls Mine, Bowman.	Blackburn Mine, Templeton
Silica	0·48	1·80	0·64	0·06	0·36
Iron oxide ... } Alumina ... }	1·00	1·30	1·30	0·72	8·72
Lime	54·20	53·30	54·40	55·70	55·60
Magnesia	0·35	0·28	0·31	0·20	0·33
Soda ... } Potash ... }	0·77	0·64	0·88	0·80	0·75
Water	0·32	0·36	0·12	0·28	0·20
Chlorine	0·44	0·40	0·67	0·65	0·50
Fluorine	3·30	3·20	3·30	3·10	3·05
Carbon dioxide ...	0·66	—	1·75	—	—
Phosphorus pentoxide	39·60	40·15	37·50	39·24	39·39

* Summary Report, Mines Branch, Dept. of Mines, Ottawa, 1917, p. 110.

Buckingham township, in Quebec, is the principal seat of th phosphate industry in Canada. Phosphate-rock is there manu factured into fertilizers, phosphorus and its compounds, but th raw material is almost entirely imported from the United States.

The only known deposits of phosphate-rock of sedimentar formation in Canada are certain low-grade coprolitic bed occurring in Quebec and Nova Scotia, and containing about 3 to 44 per cent. tri-calcium phosphate; a thin bone-bed in th Cretaceous rocks of the Wilson River, Manitoba, carrying abou 30·7 per cent. tri-calcium phosphate; and an extensive regio in Alberta where there is a steeply-inclined bed of low-grade, ha black phosphate, 12 inches in width, lying conformably wit the bedding-planes of the enclosing Rocky Mountain quartzites.

The Alberta deposits were carefully examined in the autum of 1915 by officers of the Canadian Department of Mines, wh

reported that the low grade of the material (43·7 per cent. tri-calcium phosphate) and the high cost of mining would hardly permit of these deposits being profitably worked.

Production of Phosphates in Canada.

Year	Quantity (long tons).			Value (£).*		
	Quebec.	Ontario.	Total.	Quebec.	Ontario.	Total.
1913	344	—	344	759	—	759
1914	495	357	852	1,016	500	1,516
1915	179	15	194	500	21	521
1916	170	11	181	488	36	524
1917	110	23	133	256	53	309
1918	125	—	125	250	—	250
1919	20	1	21	362	6	368

Imports of Phosphate-Rock and Superphosphate into Canada.
(Fiscal years ending March 31.)

Year	Phosphate-Rock.	Superphosphate.			
	Value (£)*	Quantity (long tons).		Value (£).*	
	From the United States.	From the United Kingdom.	From the United States.	From the United Kingdom.	From the United States.
1913	5,029	64	800	1,543	15,250
1914	3,379	85	829	1,645	17,127
1915	3,567	67	754	1,323	19,678
1916	3,139	58	906	1,147	23,082
1917	4,517	15	1,299	392	34,270
1918	14,549	6	1,143	139	42,806
1919	18,234	—	1,385	—	64,144

Exports of Phosphates from Canada.
(Fiscal years ending March 31.)

Year	Quantity (long tons).	Value* (£).
1913	—	—
1914	167	104
1915	54	37
1916	252	709
1917	12	42
1918	—	—
1919	—	—

Note.—The whole of the exports were sent to the United States.

* Values converted to £ sterling at the rate of 1 dollar = 4*s.* 2*d.*

West Indies.

In the Island of Redonda, Leeward Islands, West Indies, deposits of aluminium phosphate occur as veins in the volcanic rock of which the island is composed. The thickness of the veins varies from a few inches up to 2 feet. Official reports give no statistics of the amount of phosphate exported from the island, but considerable quantities have been shipped to the United States. No shipments were made between 1912 and 1915, although in the latter year a stock of 1,235 tons of phosphate awaited shipment. The Blue Book for 1917-18 states that 80 men were at that time employed on the deposits.

India.

Phosphate of lime occurs in the Cretaceous formations of Pondicherry, notably in the neighbourhood of Valudayur, where a bed of black phosphatic nodules was worked some years ago; but the operations were not successful. The distribution of the phosphatic nodules within the bed is exceedingly irregular, varying between 27 lb. and 47 lb. per 100 cubic feet of rock. The nodules contain from 56 to 59 per cent. tri-calcium phosphate, with about 15 per cent. carbonate. It has been estimated that the bed contains 8 million tons of phosphatic nodules.

The Department of Industries in Madras is now considering the problem of the exploitation and development of the deposits of phosphatic nodules in the Trichinopoli district; and the establishment of an experimental factory is contemplated at Trichinopoli for the production of flour phosphate.

Nodules of phosphate of lime and layers of phosphate-rock occur in a band of shale at the base of the chert beds immediately overlying the Mussoorie limestone on the Midlands Estate of the Dehra Dun district, United Provinces. The nodules contain 75 per cent. of tri-calcium phosphate, and the phosphate-rock 66 per cent. Exposures of the deposit have been found at three places in a length of a mile.

Apatite occurs abundantly in the mica-pegmatites near Kodarma, in Hazaribagh, but it is discarded during mining operations, and considerable quantities of this mineral lie on the waste-dumps. Apatite also occurs near Jothvad, in Bombay, where the mineral constitutes from one-fourth to one-third of the rock; also at the manganese mines of Garbham, Ramabhadrapuram, and Devada, in Madras. The apatite is apparently not considered of any value, the whole output going to the waste-dumps.

Palestine.

The important deposit of phosphate situated between Es Salt and Ammon, in the valley of the Jordan, was known and generally prospected prior to the war. Certain workings and test borings had been made, but no organized effort had been brought to bear

on many of the phosphate beds in the area. It is probable that difficulties of railway communication had militated against the commercial development of the deposit. Pre-war references to the deposit describe it as being in an inaccessible position, the nearest railway line being at Jerusalem, which is approximately 30 to 35 miles in a direct line from Es Salt.

As a result of the military operations in Palestine, however, a railway was constructed from Medina to Haifa. The line runs parallel to the Jordan about 30 miles east of the Jordan valley, and consequently passes very close to the eastern side of the deposit at Es Salt. The railway follows a circuitous route to the sea, the distance traversed between Ammon and Haifa being 151 miles.

During 1916 a careful examination of the deposits, made by a German official attached to the Turkish Army, indicated that they were of greater importance than had originally been suspected. The phosphate beds, of which there are several, are situated on either side of the caravan route from Jerusalem to Ammon, and are reported to be of two types, namely, plateau phosphates and rich deposits.

Plateau Deposits.—Large areas within the plateau phosphate district are covered with fairly thick deposits. At Wadi-el-Kabou and Wadi Siron, there are two phosphate beds, one close to the surface and the other 60 to 70 metres (185 to 215 feet) below the surface. They occur in three areas, namely: (1) Abou Tarah; (2) west of Carbet Botin; (3) north-west of Hirbet Aboutine.

On the western side of Abou Tarah there are three phosphate strata, the uppermost of which is 10 metres (32 feet 6 inches) in width, the others being 7 metres (22 feet 9 inches), and 3 metres (9 feet 9 inches) in width respectively. The outcrop is 150 metres (about 490 feet) in length, and a test carried along the whole length averaged 51 per cent. of tri-calcium phosphate. The thickness of the strata, the uppermost of which is under a loose cover about 1 to 2 feet deep, ranges from 12 inches to 2 feet, and these deposits are, therefore, unimportant.

The plateau west of Carbet Botin flanks the road from Es Salt to Ammon on both sides. At a point about 5 miles from Es Salt a bed of phosphate several metres deep was found, 23 feet below the surface, showing 54·6 per cent. of tri-calcium phosphate. Various other borings were made, and the average thickness of deposits on this plateau was estimated at 3 metres (9 feet 9 inches) at a depth of a few metres below the surface. The average of all tests made on this plateau showed 54·1 per cent. of tri-calcium phosphate.

The plateau north-west of Hirbet Aboutine is a prolongation, in a north-easterly direction, of that west of Carbet Botin. Here are several deposits of considerable extent, averaging 3 metres (9 feet 9 inches) in thickness, and containing on an average 47·3 per cent. of tri-calcium phosphate.

Rich Deposits.—The rich zone extends from Djebel Abou el Bewati on the south up to Hirbet Aboutine on the north, but its continuation beyond Djebel Abou Tarah to the south and Djebel Oum el Kaoub on the north, was not proved.

At Abou el Bewati the occurrence of powdery phosphate at 876·5 metres (2,850 feet) above sea-level is regarded as important. The analysis showed 78·05 tri-calcium phosphate. To the south the powdery phosphate deposit gives place to rock phosphate occurring at about 40 metres (130 feet) below the surface. At its southern limit the analysis of the powdery phosphate falls to 58/52 per cent. Tests of the rock, however, showed from 63·01 per cent. to 67·17 per cent.

No rich phosphate was found to the south of this mountain, but to the north on the Djebel Siron there are a large number of deposits of high-grade material.

A shaft was sunk at one point here and a sample gave an analysis of 78·14 per cent. The deposit is apparently very thick (over 20 metres—65 feet), and 22 analyses showed an average test of 66·1 per cent. The deposit is in layers of varying content rising as high as 80·84 per cent. and falling at the bottom of the shaft to 59·3 per cent.

South of the shaft the deposit increases in depth from the surface and it appears to lie on an incline of 43° towards the west. Here a percentage content of 82·8 per cent. was established apparently by boring through the layer. At another excavation some distance away the thickness of the deposit was found to be reduced to 10 metres (32 feet 6 inches), but the analysis was found to be between 83 and 84 per cent. At a third excavation the thickness was found to be less still, but the analysis was 82·4 per cent.

North of the shaft, some distance away, the thickness of the layer was found to decrease from 4 metres to 2 metres (13 feet to 6 feet 6 inches), but the tests were still from 80·5 to 83·8 per cent.

At Carbet Botin, various tests were made in existing excavations and several borings were made. The existence of phosphate beds, some of which were up to 8 metres (26 feet) thick, was established, and test analyses showing from 68·19 to 83·4 per cent. were made. The average of all tests was found to be 72·07 per cent.

Again, at Hirbet Aboutine, excavations were made and a bed 6·30 metres (20 feet 6 inches), 5 metres (16 feet 3 inches), and 3 metres (9 feet 9 inches), in thickness at various points was found, analyses at the three points showing 80·1 per cent., 61·8 per cent. and 71 per cent. respectively. It is not clear whether these tests were over only one bed or over three different deposits. At its northern extremity this deposit still shows a thickness of 2·5 metres (8 feet 2 inches).

Straits Settlements.

Christmas Island.

Christmas Island lies in the Indian Ocean, about 190 miles south of the western extremity of Java. The phosphate deposits are similar to those on Ocean Island. The rock contains on an average about 80 per cent of tri-calcium phosphate.

In the year 1912 Christmas Island produced about 300,000 tons of phosphate. Large reserves are available.

Production of Phosphate-Rock in Christmas Island.

Year.	Quantity (long tons).
1913	149,956
1914	93,703
1915	23,731
1916	44,209*
1917	89,889*
1918	53,370*
1919	

* Exports.

Australia.†

New South Wales.—Small quantities of phosphate of lime are known to occur in many of the limestone caves found in the State. The deposits are invariably the result of the decomposition of animal remains and, where mined, the rock carries a high percentage of tri-calcium phosphate.

The only deposit of any considerable value worked during the period under review was in the Wellington division, which produced the bulk of the phosphate-rock mined in the State. These deposits were exhausted in 1918.

Victoria.—Phosphate mining in Victoria is confined to workings situated near Mansfield. The phosphate-rock is obtained by underground mining, the material obtained being picked over at the mine and the selected rock shipped to Melbourne.

Queensland.—Deposits of phosphate-rock are being mined on Holbourne Island, which is situated about 20 miles east-north-east of the town of Bowen. The phosphate-rock varies considerably as regards the phosphoric acid content, and it is unsuitable for the manufacture of superphosphate. Including the lowest grades there are about 400,000 tons of phosphate-rock available.

† Annual Reports of the Department of Mines, New South Wales. Annual Reports of the Secretary for Mines, Victoria. Reviews of mining operations in South Australia. Trade and Customs and Excise Revenue of the Commonwealth of Australia (Annual).

*South Australia.**—Phosphate-rock, almost invariably associated with Cambrian or pre-Cambrian limestone, occurs abundantly over wide areas of South Australia. The associated minerals are chiefly limonite and manganese oxide, both occurring sparingly, with silica in the form of chert and quartz. Copper has been noted in the form of copper phosphate in the quarries of the Pekina district, and hæmatite in veins up to half an inch in thickness has been found traversing the phosphate-rock of the Bendleby deposits.

Phosphate-rock is worked at a large number of localities, between Willunga in the south and Carrieton in the north, and between Clinton in the Yorke Peninsula and Bright to the north of Eudunda. The principal producing districts are the Belvedere including Kapunda, and Moorooroo, north of Adelaide; the Willunga and Noarlunga districts to the south of Adelaide; and the Tarcowie and Pekina districts north-east of Port Pirie.

The phosphate-rock is mined or quarried in the simplest manner, usually by open-quarrying, but sometimes, as in the case of the St. John's and McArthy's quarries, by means of an incline and a rough pillar and stall system. Owing to the erratic nature of the deposits, no attempt is made to block-out reserves, the only development work undertaken being the driving of small prospecting levels ahead of the workings.

The grade of rock produced averages about 60 per cent. tri-calcium phosphate in the " firsts " and over 50 per cent. in the " seconds." Rock below 50 per cent. is for the most part unsaleable.

Large deposits of aluminium phosphate occur in the Belvedere, Clinton and Orroroo districts, but these occurrences have not been worked.

Superphosphates are manufactured in Australia chiefly from high-grade imported rock. Before the war high-grade pyrites was imported from Spain for the manufacture of the sulphuric acid required for the production of superphosphate, but during the war it was found impossible to obtain Spanish pyrites, and crude sulphur imported from Sicily and Japan was used for the production of the acid. One company produces a " Standard " super-brand guaranteed to contain 36 per cent. of tri-calcium phosphate in water-soluble form from the imported rock, and a brand containing 30 per cent. tri-calcium phosphate. The works are situated at Wallaroo and Port Adelaide and have a capacity of over 70,000 tons per annum. Other works are situated at Torrensville and Port Adelaide, and have a capacity of 40,000 to 50,000 tons per annum. In addition the metallurgical works at Cockle Creek have erected a large plant for the manufacture of superphosphate, the phosphate-rock being obtained from Ocean Island.

* The Phosphate Deposits of South Australia, by R. L. Jack; Geol. Surv. S. Austr.; Bull. No. 7, 1919.

During the period under review, considerable attention was given to the apatite-bearing pegmatite veins of the Boolcoomatta district.

Early in 1919 an important discovery of apatite was made near the old Boolcoomatta Station. The mineral was found occurring in lenticular masses of considerable size. The main exposure has a length of 90 feet and an estimated average width of 9 feet, the extension in depth being unknown. Other deposits were found scattered over a considerable area of the Boolcoomatta district. Analyses of various samples of apatite from these areas show insoluble matter ranging from 14·9 to 45·4 per cent., and phosphate equivalent to 48·70 to 77·78 per cent. tri-calcium phosphate.

*Western Australia.**—Coprolite deposits, interbedded with ferruginous sandstones and chalk, have been proved to occur over a distance of 22 miles in the Dandarragan district, which is situated about 20 miles to the west of Moora, on the Midland Railway. The coprolite beds average about 3 feet in thickness, and contain from 15·32 to 39·34 per cent. phosphorus pentoxide. No production was reported from this district during the period under review.

High-grade phosphate of lime has been obtained from the numerous caves that occur in the limestone hills between Perth and Geraldton. The deposits are limited in extent, and the production therefrom is only of local value.

The only deposits worked on a commercial scale are the phosphate beds that occur on all the islands from the Ashmore Shoals to the Abroholos Islands. So far as is known, the bulk of the high-grade phosphate-rock on these islands has been worked out, but there still remain large quantities of low-grade material which, if ground, could be profitably employed on the wetter farming lands of the State.

Production of Phosphates in Australia.

Year.	New South Wales.		Victoria.		South Australia.	
	Quantity (long tons).	Value (£).	Quantity (long tons).	Value (£).	Quantity (long tons).	Value (£).
1913 ...	—	—	—	—	5,950	6,545
1914 ...	700	1,055	—	—	6,083	6,691
1915 ...	1,100	—	—	—	4,614	5,536
1916 ...	2,042	—	400	1,150	5,013	5,839
1917 ...	2,000†	4,500	1,525	1,525	5,101	6,064
1918 ...	460‡	1,400	3,384	3,384	8,074	10,773
1919 ...	576	2,016	2,491	2,491	5,950	8,982

* Geol. Surv. Western Australia. Miscellaneous Reports, Series V., No. 61, 1917, Bull. No. 74.

† In addition, some 40 to 50 tons of material, said to be rich in phosphates, were raised during prospecting operations.

‡ Including 160 tons of phosphate of lime used in smelting.

*Exports of Phosphate-Rock from Australia.**
(Fiscal years ending June 30.)

Year.	Domestic Produce.		Foreign Produce.	
	Quantity (long tons).	Value (£).	Quantity (long tons).	Value (£).
1915	1,117	3,429	—	—
1916	3,742	10,507	50	188
1917	3,301	8,464	—	—
1918	3,500	9,810	—	—
1919	2,200	6,773	—	—

* The whole of these exports went to New Zealand.

Exports of Superphosphate from Australia (Domestic Produce.)†
(Fiscal years ending June 30.)

To	Quantity (long tons).				
	1915.	1916.	1917.	1918.	1919.
New Zealand	13,963	40,355	23,881	34,825	17,056
Fiji	1,587	113	288	164	214
Total to British Possessions ...	15,550	40,468	24,169	34,989	17,270
Samoa (German)	3	—	—	—	—
Java	—	500	—	—	—
Other Foreign Countries ...	—	—	9	—	5
Total to Foreign Countries ...	3	500	9	—	5
TOTAL	15,553	40,968	24,178	34,989	17,275
	Value (£).				
New Zealand	58,300	153,517	104,063	178,865	94,512
Fiji	5,909	621	1,385	821	1,086
Total to British Possessions ...	64,209	154,138	105,448	179,686	95,598
Samoa (German)	13	—	—	—	—
Java	—	2,122	—	—	—
Other Foreign Countries ...	—	—	41	—	23
Total to Foreign Countries ...	13	2,122	41	—	23
TOTAL	64,222	156,260	105,489	179,686	95,621

† In addition, superphosphate to the value of £15 was sent to Norfolk Island during the period 1913–1919.

Imports of Phosphate-Rock into Australia.
(Fiscal years ending June 30.)

From	1915.	1916.	1917.	1918.	1919.
	Quantity (long tons).				
India	—	—	—	1	—
New Zealand	—	3	—	—	—
Christmas Island	13,724	26,866	47,885	17,864	11,938
Gilbert and Ellice Islands ...	—	—	92,501	112,861	62,962
Ocean Island	98,855	96,049	—	—	—
Total from British Possessions	112,579	122,918	140,386	130,726	74,900
United States	5,132	—	—	—	—
Bismarck Archipelago ...	300	—	—	—	—
Makatea Island	28,638	17,367	6,634	—	7,178
New Caledonia	—	—	1,190	—	—
Pleasant Island	17,318	47,704	27,418	51,426	58,513
Society Islands	4,300	2,700	2,200	—	—
Tatakotoroa	4,960	—	—	—	—
Total from Foreign Countries	60,648	67,771	37,442	51,426	65,691
TOTAL	173,227	190,689	177,828	182,152	140,591
	Value (£).				
India	—	—	—	3	—
New Zealand	—	12	—	—	—
Christmas Island	30,771	65,911	148,553	82,609	59,094
Gilbert and Ellice Islands ...	—	—	207,809	239,317	131,563
Ocean Island	227,164	222,566	—	—	—
Total from British Possessions	257,935	288,489	356,362	321,929	190,657
United States	9,816	—	—	—	—
Bismarck Archipelago ...	528	—	—	—	—
Makatea Island	65,170	38,209	17,564	—	15,791
New Caledonia	—	—	2,939	—	—
Pleasant Island	41,713	107,499	63,669	112,011	127,588
Society Islands	11,209	6,237	4,450	—	—
Tatakotoroa	10,912	—	—	—	—
Total from Foreign Countries	139,348	151,945	88,622	112,011	143,379
TOTAL	397,283	440,434	444,984	433,940	334,036

Imports of Superphosphates into Australia.
(Fiscal years ending June 30.)

From	Quantity (long tons).				
	1915.	1916.	1917.	1918.	1919.
United Kingdom	6,989	5	—	—	—
New Zealand	—	5	—	—	—
Total from British Possessions	6,989	10	—	—	—
Belgium	100	—	—	—	—
Germany	24	—	—	—	—
Netherlands	5,905	—	—	—	—
Japan	12,101	2,880	10	—	—
Total from Foreign Countries	18,130	2,880	10	—	—
TOTAL	25,119	2,890	10	—	—
	Value (£).				
United Kingdom	16,282	12	—	—	—
New Zealand	—	5	—	—	—
Total from British Possessions	16,282	17	—	—	—
Belgium	958	—	—	—	—
Germany	60	—	—	—	—
Netherlands	19,032	—	—	—	—
Japan	43,556	10,291	61	—	—
Total from Foreign Countries	63,606	10,291	61	—	—
TOTAL	79,889	10,308	61	—	—

New Zealand.*

The known phosphate deposits of New Zealand are of small size, and, with the exception of those in the Clarendon-Milton district of Otago, of little commercial importance. The phosphates in the Milton district occur as segregations in limestones of Miocene age. Parcels of high-grade rock yield 30 to 36·7 per cent. phosphorus pentoxide, equivalent to 65·3 to 80·2 per cent. tri-calcium phosphate. The total iron oxide and alumina varies from 1·4 to 9 per cent.

Superphosphate production increased considerably during the war in New Zealand, which will in the future share the output of Nauru Island with Australia and the United Kingdom.

* New Zealand Mines Statements (Annual). Trade and Shipping of New Zealand (Annual).

Production of Phosphate-Rock in New Zealand.

Year.	Quantity (long tons).
1913	11,000
1914	10,743
1915	—
1916	7,600
1917	5,050
1918	5,000
1919	4,000

Imports of Phosphate-Rock and Guano into New Zealand.

From	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ...	17	16	35	25	—	—	20
India	—	—	—	—	—	1	—
Seychelles	—	5,150	4,350	—	—	—	—
Straits Settlements ...	—	5,779	300	—	—	—	—
Australia	643	1,638	4,279	6,185	5,362	1,879	3,184
Gilbert and Ellice Islands	92	—	—	4,000	—	—	—
Malden Islands ...	4,823	5,269	1,885	—	—	—	—
Total from British Possessions	5,575	17,852	10,849	10,210	5,362	1,880	3,204
Madagascar	—	2,848	3,410	—	—	—	—
New Caledonia ...	3,217	—	5,234	2,171	6,124	5,084	7,851
Society Islands ...	—	24	—	545	250	—	—
Tuamotu Archipelago	—	—	20,026	16,366	24,922	22,901	29,561
Total from Foreign Countries	3,217	2,872	28,670	19,082	31,296	27,985	37,412
TOTAL ...	8,792	20,724	39,519	29,292	36,658	29,865	40,616
	Value (£).						
United Kingdom ...	131	130	656	241	—	10	462
India	—	—	—	—	—	3	—
Seychelles	—	13,298	13,730	—	—	—	—
Straits Settlements ...	—	13,257	1,260	—	—	—	—
Australia	2,052	5,877	16,019	21,289	17,937	6,010	10,752
Gilbert and Ellice Islands	284	—	—	5,720	—	—	—
Malden Islands ...	13,311	15,174	4,664	—	—	—	—
Total from British Possessions	15,778	47,736	36,329	27,250	17,937	6,023	11,214
Madagascar	—	9,255	11,458	—	—	—	—
New Caledonia ...	7,811	—	12,166	4,042	10,342	10,169	17,435
Society Islands ...	—	74	—	1,009	412	—	—
Tuamotu Archipelago	—	—	45,578	22,664	41,271	37,945	65,209
Total from Foreign Countries	7,811	9,329	69,202	27,715	52,025	48,114	82,644
TOTAL ...	23,589	57,065	105,531	54,965	69,962	54,137	93,858

mports of all other Phosphates into New Zealand.

From	Quantity (long tons).					
	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom	325	—	1	—	—	100
Egypt...	—	—	10,140	11,225	—	10,000
India	—	—	—	5	—	—
Australia	1	436	385	50	120	—
Total from British Possessions	326	436	10,526	11,280	120	10,100
Belgium	199	—	—	—	—	—
Germany	424	—	—	—	—	—
Netherlands	50	80	—	—	—	—
United States	10	—	—	—	—	—
Total from Foreign Countries	683	80	—	—	—	—
TOTAL	1,009	516	10,526	11,280	120	10,100
	Value (£)					
United Kingdom	1,064	9	21	—	—	583
Egypt...	—	—	39,032	43,217	—	49,500
India	—	—	—	47	—	—
Australia	9	1,641	1,627	138	383	—
Total from British Possessions	1,073	1,650	40,680	43,402	383	50,083
Belgium	703	—	—	—	—	—
Germany	1,474	—	—	—	—	—
Netherlands	180	239	—	—	—	—
United States	25	—	—	—	—	—
Total from Foreign Countries	2,382	239	—	—	—	—
TOTAL	3,455	1,889	40,680	43,402	383	50,083

Imports of Superphosphates into New Zealand.

From	Quantity (long tons).					
	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom	13,923	5,915	406	—	—	—
Australia	6,119	33,603	28,055	24,793	33,499	17,604
Total from British Possessions	20,042	39,518	28,461	24,793	33,499	17,604
Belgium	178	—	—	—	—	—
Germany	18,511	277	—	—	—	—
Netherlands	11,077	1,196	—	—	—	—
United States	50	—	—	—	—	—
Japan	6,283	13,259	5,869	3,954	—	—
Total from Foreign Countries	36,099	14,732	5,869	3,954	—	—
TOTAL	56,141	54,250	34,330	28,747	33,499	17,604
	Value (£).					
United Kingdom	48,954	20,580	1,444	—	16	—
Australia	25,428	136,507	121,229	120,355	174,328	96,638
Total from British Possessions	74,382	157,087	122,673	120,355	174,344	96,638
Belgium	672	—	—	—	—	—
Germany	62,267	885	—	—	—	—
Netherlands	37,925	8,322	—	—	—	—
United States	163	—	—	—	—	—
Japan	24,526	51,956	17,417	19,088	1,035	—
Total from Foreign Countries	125,553	61,163	17,417	19,088	1,035	—
TOTAL	199,935	218,250	140,090	139,443	175,379	96,638

Nauru Island.*

Immense deposits of phosphate-rock occur in the island of Nauru, which is situated just south of the equator, in longitude 167° E. The material is easily mined, and shipping facilities are favourable. The reserves on the island are estimated at from 80 to 100 million tons of phosphate-rock carrying 85 to 86 per cent. of tri-calcium phosphate. During the war, this island was captured from the Germans, and, under Article 6 of the Nauru Island Agreement Bill, the title to the phosphate deposits on the island is vested in a Board of Commissioners appointed by the Governments of the United Kingdom, the Commonwealth of Australia, and the Dominion of New Zealand, the arrangement providing

* Board of Trade Journal, 1919, Dec. 18, p. 771. The New Zealand Journal of Agriculture, Dec., 1920, p. 297.

that 84 per cent. of the output should be divided equally between the United Kingdom and Australia, and that the New Zealand share should be 16 per cent.

Formerly these deposits, as well as those on Ocean Island, were owned by the Pacific Phosphate Company of London and Melbourne, but under the new arrangement the company's rights and property were transferred in July, 1920, to the Board of Commissioners.

The phosphate occurs in surface deposits which are scattered over the whole interior of Nauru Island. The underlying rock is a hard compact coral limestone which in places has been greatly denuded, the harder portions being left standing as pinnacles which may attain a height of 30 feet. The phosphate-rock is found chiefly between these pinnacles and often covers them entirely. Quarrying operations are carried out by pick-and-shovel methods, the excavated material being transported to the tramways by cable hoists and subsequently crushed and dried. Shipping operations have presented a difficult problem, but this has now been solved by putting down mooring-buoys close inshore, in about 1,000 feet of water, at which vessels can load from lighters in fine weather.

*Phosphate Produced in and Exported from Nauru Island.**

Year.	Raised (long tons).	Shipped (long tons).
1913	133,000	133,000
1914	72,000	54,000
1915	92,000	85,000
1916	97,000	104,000
1917	98,000	97,000
1918	83,000	80,000
1919	60,000	68,000

Ocean Island.†

Ocean Island is one of the Gilbert Islands, which, with Ellice Islands, form the Gilbert and Ellice Islands Colony. It is administered by a High Commissioner through a Resident Commissioner stationed at Ocean Island.

The phosphate-rock is found in surface deposits of large size and has a very high degree of purity. The best deposit is on the central tableland, where beds of rock-phosphate extend to a depth of 50 feet. Their origin is attributed to the leaching of guano and the replacement of the underlying limestone by phosphatic solutions.

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* Information supplied by the British Phosphate Commissioners, London.
† N.Z. Journ. Agric., Dec., 1920, p. 312.

The phosphate is mined by removing the overburden and breaking out the rock with pick and shovel. The excavated material is run down from the tableland by gravity tramway to driers and bins near the jetty. Owing to the lack of harbour accommodation, vessels are obliged to load at sea. The phosphate is carried by car to the jetty and there loaded into baskets, which are conveyed by boat to the ship. The annual output during the period under review ranged from 215,000 to 53,000 tons of 85 per cent. phosphate.

It has been estimated that the reserves of high-grade rock on Ocean Island exceed 50 million tons. As in the case of Nauru Island, the future output of Ocean Island phosphates will be shared by New Zealand, Australia, and the United Kingdom.

*Phosphate Produced in and Exported from Ocean Island.**

Year.	Raised (long tons).	Shipped (long tons).
1913	215,000	205,000
1914	158,000	153,000
1915	126,000	130,000
1916	105,000	93,000
1917	101,000	93,000
1918	70,000	73,000
1919	53,000	64,000

FOREIGN COUNTRIES.

Belgium.†

Phosphates occur in Belgium, either as beds of phosphatic nodules in a matrix of clay, or as beds of phosphatic chalk in Tertiary and Cretaceous rocks. Before the high-grade American and Pacific Islands deposits were developed, the Belgian phosphates were of considerable importance, but latterly the output has greatly declined, as the average grade of the rock obtainable is only 40 to 45 per cent. tri-calcium phosphate. The principal phosphate-mining region is situated at Ciply and Mesvin, near Mons, in the battle area of Flanders.

Before the war Belgium was an important manufacturer of superphosphate. The industry was centred at Antwerp, and there were 33 factories manufacturing superphosphate, sixteen of which made their own acid. Large quantities of high-grade rock were imported from Algeria, Tunis and Florida, while some was obtained from Aruba in the West Indies and also from the Somme district in France. The low-grade domestic rock was mixed with high-grade imported phosphates.

Exports of superphosphates were on a large scale, the bulk being shipped to France, Spain, Germany, the Netherlands, Great Britain and Portugal.

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* Information supplied by The British Phosphate Commissioners, London.

† Statistique des Industries Extractives et Métallurgiques en Belgique (Annual).

Production of Phosphates in Belgium.

Year	Phosphate of Lime.		Phosphatic Chalk.	
	Quantity (long tons).	Value* (£).	Quantity† (long tons).	Value* (£).
1913	215,894	78,246	186,000	12,486
1914	103,637	41,789	188,000	9,747
1915	16,087	7,472	67,000	3,035
1916	76,491	53,356	178,000	9,248
1917	136,077	61,174	61,000	11,400
1918	60,708	60,520	168,000	16,344
1919	89,508	123,180	89,000	20,460

* Values converted to £ sterling at the rate of 25 francs = £1.
† Quantity converted to tons assuming 1 cu. yd. of phosphatic chalk=1½ ton.

France.‡

Phosphate-mining in France is confined to the departments of the Aisne, Ardennes, Meuse, Oise, Pas de Calais and Somme, all of which were in the war area. In the Aisne, Oise, Pas de Calais and Somme districts, the rock occurs for the most part as phosphatic chalk beds of Upper Cretaceous age. In the Meuse, Ardennes and Marne districts, the phosphates occur in the Lower Cretaceous Greensands, in narrow bands from 2 to 10 inches in thickness.

Before the war the annual output of superphosphate was approximately 1,890,000 tons, from 75 factories. Imports of high-grade rock were obtained chiefly from Tunis, the United States and Algeria, with smaller quantities from Egypt, the Pacific Islands and Belgium.

Formerly the French domestic deposits were of considerable importance, but, as the grades range from 40 to 65 per cent. tri-calcium phosphate, they are now unable to compete with the cheaper high-grade phosphates of Florida and North Africa, and production has consequently declined.

In Algeria, Tunis and Morocco, France possesses large resources of phosphate. In her Pacific possessions, particularly on the islands of Tahiti and Makatea, in the Society group, further large reserves of high-grade phosphate are being worked.

Phosphate deposits are also mined on the island of Salut, and on the Grand Connétable Island, near the coast of French Guiana.

During the war the production of superphosphates in France decreased considerably, chiefly owing to difficulty in obtaining supplies of sulphuric acid, large quantities of which were used for munition purposes.

‡ Statistique de l'Industrie Minérale en France et en Algérie (1914-1918).

French Production, Imports and Exports of Phosphates and Superphosphates.

Year	Quantity (long tons).					
	Phosphates.			Superphosphates.		
	Production.	Imports.	Exports.	Production.	Imports.	Exports.
1913 ...	330,000	925,671	20,802	1,889,000	99,202	142,894
1914 ...	270,000	650,799	10,811	1,574,000	57,220	115,347
1915 ...		320,527	1,767	590,000	13,812	58,862
1916 ...	25,500	281,311	1,699	344,000	4,056	12,164
1917 ...		132,613	617	239,000	1,853	3,789
1918 ...		229,648	35	405,000	6,071	2,837
1919 ...		494,562			12,748	

Germany.

There was probably no country which gave so much careful attention to the use of phosphates in agriculture in the pre-war period as Germany, and, while the United Kingdom was the first producer of superphosphate, there is no doubt that German practice was very largely responsible for the rapid development of its use as a fertilizer.

The German consumption of raw phosphate in 1913 was approximately one million tons, equivalent to a production of, say, 1,800,000 tons of superphosphate.

No deposits of phosphate-rock of commercial importance were at that time known in Germany, and consequently the whole of the rock required was imported, principally from the United States, Tunis, Algeria and Belgium.

Before the war Germany possessed very large reserves of high-grade phosphate in the deposits of various Pacific islands, particularly those worked on the Island of Nauru. This island was captured by the Australian Fleet shortly after the outbreak of war, and the phosphate deposits have since been acquired by the Governments of United Kingdom, Australia and New Zealand.

The blockade which was instituted against Germany immediately on the outbreak of war prevented the importation of phosphates from foreign sources. Superphosphate consequently became very scarce and dear, and its place had to be taken as far as possible by basic-slag. Even with the increased production of basic-slag there was still a very grave shortage of phosphates in Germany, and every effort was made to discover workable deposits within the country.

It was not until 1918, however, that a deposit was found close to Amberg, in the vicinity of Nuremberg, Bavaria. This deposit

attains a thickness of about ten feet in many places, and is in the form of bi-basic phosphate of lime. In certain workings a product was found containing 80 per cent. tri-calcium phosphate. In places, however, the percentage was as low as 30. The deposit as a whole has been estimated to average 35 per cent. tri-calcium phosphate.

Holland.*

During the period under review, efforts were made to discover deposits of phosphate-rock in Holland. Deposits carrying 25 to 30 per cent. phosphate of lime were found in the Drenthe and Overyssel provinces of north-eastern Holland, and a factory was erected to prepare the material for market. A bed of phosphate-rock, varying in thickness from 7 inches to 3 feet, was found at Ootmarsum, in the Twente district. The rock contains on an average from 15 to 20 per cent. phosphate of lime, but, on account of the irregularity of the bed, it is difficult and expensive to mine, and only about 30 tons are produced daily.

Holland produces a large amount of superphosphate and before the war had an exportable surplus.

Italy.

A deposit of rock-phosphate has been proved to cover an extensive area near Donna Lucata, south of Syracuse, in Sicily. The phosphates occur as nodules, varying in size and containing up to 33 per cent. of tri-calcium phosphate. It is estimated that the deposit contains about 2,000,000 tons of available phosphate-rock.

Imports of Phosphates into Italy.

Year.	Quantity (long tons).
1913	521,262
1914	505,737
1915	449,558
1916	427,727
1917	226,460
1918	227,956
1919	442,096

Norway.†

At Oedegaarden, near Kragerö, in Norway, important deposits of apatite have been mined continuously for many years, the mineral occurring as veins traversing gabbro.

Previous to 1914 more than 140,000 tons of mineral had been extracted from the deposits in this district, the yearly output averaging about 740 tons.

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* American Fertilizer, 1920, **52**, No. 5, 138.

† Norges Bergverksdrift (Annual). Report on the Commerce and Industry of Norway (Department of Overseas Trade, London).

Production of Apatite in Norway.

Year.	Quantity (long tons).	Value* (£).
1913	745	1,613
1914	738	1,613
1915	1,870	5,108
1916	2,200	7,634
1917	1,803	17,204
1918	4,489	51,613
1919		

* Values converted to £ sterling at the rate of 18·6 Kroner = £1.

Imports of Phosphate-Rock and Superphosphates into Norway.

Year.	Phosphate-rock (long tons).	Superphosphates (long tons).
1913		4,322
1914		9,021
1915		2,715
1916		10,964
1917	4,526	36,831
1918	22,622	—
1919	14,687	11,252

Russia.

Phosphate deposits of great importance occur in the Jurassic and Cretaceous rocks in the provinces of Vladimir, Krostrom, Viatka and Yaroslav, in northern Russia, and in the governments of Podolia and Bessarabia in the south.

Before the war, the southern deposits only were worked, chiefly by underground mining operations. The rock, which is said to have averaged about 75 per cent. of tri-calcium phosphate, was transported to Poland for manufacture into superphosphates. The deposits are estimated to contain about 80 million tons of phosphate-rock. The northern deposits have so far not been worked, but careful geological examination has shown that they contain important quantities of phosphate.

In addition to these two main phosphate-bearing regions, deposits of Cretaceous phosphate-rock are reported to occur in the governments of Smolensk, Saratoff, Orel, Kazan and elsewhere in Central Russia.

Production statistics for the period under review are incomplete. The outputs for 1913 and 1914 are estimated at 25,000 and 15,000 tons respectively.

As a result of the revolution, the superphosphate factories of Russia have suffered to a very serious extent, and it was not until 1919 that the Soviet Government made any serious attempt to provide the Russian peasant with supplies of superphosphate.

The principal Russian factories were situated at Petrograd, Kineschma and Nijni Novgorod, and efforts were in the main

directed to using phosphate-rock of native production for the manufacture of superphosphate. The extent to which these efforts succeeded is not known.

Spain.*

The only phosphate deposits extensively worked in Spain are apatite veins at Aldea Moret, in the province of Cáceres.

Large quantities of phosphate-rock are imported annually, chiefly from Tunis, Algeria and the United States. The high-grade Florida rock imported from the United States is used chiefly in northern Spain and Catalonia for making high-grade superphosphate. In the south the demand is for lower-grade superphosphate.

The decrease in imports during 1917 and 1918 was due to difficulties in procuring freight and export licences from the United States, and not to any diminution in the demand for phosphate.

In 1913, about 600,000 tons of superphosphate were consumed in Spain, of which about 37 per cent. was manufactured in that country, the remainder having been imported from England, France, Belgium and Holland.

Production and Imports of Rock-Phosphate in Spain.

Year.	Production. Quantity (long tons).	Imports. Quantity (long tons).
1913	3,491	250,373
1914	8,178	198,804
1915	8,934	208,676
1916	13,884	283,694
1917	27,696	128,326
1918	42,607	113,196
1919	24,633	115,986

Production, Imports and Consumption of Superphosphates in Spain.

Year	Production. Quantity (long tons).	Imports†. Quantity (long tons).	Consumption. Quantity (long tons).
1913	221,000	147,820	600,000
1914	216,000	115,018	
1915	191,037	63,212	469,717
1916	310,112	22,686	479,800
1917	353,045	11,911	418,222
1918	125,434	11	278,281
1919	133,348	5,605	

* Estadistica Minera de España. Estadistica General del Comercio Exterior de España. The American Fertilizer, 1920, **52**, No. 5, 142–144.

† Including Thomas phosphate.

Algeria.*

Large deposits of rock-phosphate occur in Algeria, in strata of Eocene age. The two most important mining districts are situated near the towns of Setif and Tebessa, in the eastern part of the country.

In 1906 a French company obtained a concession over the important deposits situated in the commune of Bordj-Redir, in the Setif district, where the rock is mined either opencast or by tunnels, and is transported 12 miles by ropeway to the railway. In the same district, deposits are being worked in the commune of Tocqueville, where the phosphate beds vary in thickness from 1 foot to 6 feet. Another French company is working the extensive M'Zaïta deposit in the commune of Maadids. The reserves of rock-phosphate at this mine have been estimated to amount to 16,500,000 tons. Throughout the Setif district the grade of the phosphate-rock averages between 58 to 63 per cent. of tri-calcium phosphate.

The most important deposits in Algeria are those at Djebel Kouif, near Tebessa. The phosphate occurs in a basin-shaped deposit composed of five separate beds, three of which are workable. The thickness of the beds worked varies from $1\frac{3}{4}$ feet to 9 feet. Where the overburden exceeds 24 feet the rock is worked by inclined tunnels, otherwise opencast methods are adopted. A branch railway, 16 miles in length, connects the mine with the railway from Tebessa to the port at Bona, but this railway is only capable of transporting about 330,000 tons of rock annually. The output from the mine is consequently controlled by the railway facilities, and not by the potential resources of the deposit.

Throughout the Tebessa district the average grade of the phosphate-rock runs from 58 to 68 per cent. tri-calcium phosphate.

Superphosphates are manufactured at Bona, Algiers and Oran, by a company which manufactures its own sulphuric acid, and which before the war was the only company producing superphosphate in Algeria.

There are several known deposits of phosphate-rock in Algeria which, up to the present, have not been worked; the most important of these are Djebel Onk and Maadids.

The former deposit is one of the largest known, and from the surveys which have been made it is estimated to contain at least 1,000,000,000 tons of high-grade rock containing from 60 to 70 per cent. tri-calcium phosphate. This deposit is situated about 50 miles to the south of Tebessa, in the district bordering on the Sahara desert, and is approximately 125 miles from the sea-coast of Algeria. At present there is no rail connection beyond Tebessa, and the line between Tebessa and Bona is fully taxed in conveying the phosphate produced from the mines at Djebel Kouif, referred to above.

* Statistique de l'Industrie Minérale en France et en Algérie (1914–1918). The Conservation of Phosphate-Rock in the United States, by W. C. Phalen, Trans. Amer. Inst. Min. Eng., 1917, **57**, 129–130.

The Algerian Government has for some time past been studying the question of improving the railway connection between Tebessa and Bona, and making the necessary extension of the line to Djebel Onk, and there appears to be very little doubt that, as soon as the necessary works have been carried through, the Djebel Onk deposit will be exploited.

It should be observed that the whole of the district around Tebessa is very rich in minerals, and more especially iron ore. Consequently, in their project for the improvement of the railway, the Algerian authorities are looking to the extension of iron-mining in Algeria in addition to the exploitation of the Djebel Onk phosphate deposit. With the improvement of railway connections, Algeria should make a very substantial advance as a phosphate producer.

Imports and Exports of Fertilizers into and from Algeria.

Year.	Exports (long tons).		Imports (long tons).	
	Phosphates.	Superphosphates.	Superphosphates.	Natural and artificial guano.
1913 ...	431,552	7,877	17,872	—
1914 ...	349,432	3,275	7,139	595
1915 ...	222,261	21,766	1,143	276
1916 ...	382,956	6,776	1,497	1,140
1917 ...	231,051	545	314	171
1918 ...	199,284	13,187	9	129
1919 ...	238,294	14,342	1	

Tunis.*

Tunis is second only to Florida as a producer of phosphate. In 1913 the Tunisian exports amounted to about 2 million tons.

The regency is very rich in phosphate deposits, and, while many of the most important phosphate beds are being worked, there are several of potential commercial importance which have not yet been developed.

In general the deposits are situated in the south of the regency and toward the Algerian border, between the 34th and 36th parallels of N. latitude, and between the 8th and 9th degrees of E. longitude.

The richest deposits occur as lenses of great extent in rocks of Middle Eocene age. The thickness of these lenses varies from a few inches up to 10 feet, but the phosphate obtainable from the lowest Eocene beds is usually of low grade.

The principal centre of the phosphate-mining industry in the regency is Gafsa, in the neighbourhood of which are situated the most important deposits of the country.

The grade of rock produced varies from 58 to 68 per cent. tricalcium phosphate; it is very friable, and is one of the types of

* Statistique Générale de la Tunisie (Annual).

rock most easily converted into superphosphate. Owing to its soft character, it is easily ground and readily worked through superphosphate plants.

Practically the whole of the output from this region is controlled by one mining company, but there is a second company at present engaged on the preliminary work of opening up an important deposit. This deposit is situated about 9½ miles south of Gafsa at Djebel M'Dilla.

The next most important deposit is situated at Kalaa Djerda, which is close to the Algerian border, and is within about 6 miles of the important Algerian deposit of Djebel Kouif. This deposit is worked in conjunction with that of Maknassy—the product of the Kalaa Djerda mine being shipped from Tunis, and that of Maknassy from Sfax.

The other deposits in Tunis which are actually being worked are Kalaat es Senam, north-west of the Kalaa Djerda deposit, and Kef Rebiba to the north of that deposit. Both these mines ship their phosphate from the port of Tunis.

Practically the whole of the Tunisian deposits may be divided into two categories—the lower grade, containing from 58 to 63 per cent. tri-calcium phosphate, and the higher grade, from 63 to 68 per cent. The moisture content averages about 4 per cent., and generally speaking, these phosphates contain less than 2 per cent. of iron oxide and alumina.

The Tunisian phosphate mines suffered very severely from the effects of the war, as the appended statistics show, the production falling from 2,038,476 tons in 1913 to 820,000 tons in 1919.

Tunisian Production and Exports of Phosphates.

Year.	Production of Phosphates.		Exports of Phosphates.		Exports of Superphosphates.	
	Quantity (long tons).	Value (£).*	Quantity (long tons).	Value (£).*	Quantity (long tons).	Value (£).*
1913 ...	2,038,476	1,820,889	1,952,980	1,984,880	13,235	37,663
1914 ...	1,373,171	1,283,960	1,404,225	1,312,989	3,213	9,141
1915 ...	1,151,196	1,076,400	1,096,164	1,024,943	10,423	29,659
1916 ...	1,024,466	1,041,204	1,018,108	951,959	17,304	49,244
1917 ...	665,726	947,234	602,595	563,446	7,343	20,896
1918 ...	848,632	1,034,993	923,006	863,035	22	62
1919 ...	820,000		1,129,000	1,520,000		

* Values converted to £ sterling at the rate of 25 francs = £1.

Dutch West Indies.

Extensive deposits of phosphate occur in Curaçao and Aruba, two islands off the coast of Venezuela.

In 1913, phosphate-mining was resumed in Curaçao after a suspension of twenty years. The deposits are of exceptional

grade, containing from 80 to 85 per cent. of tri-calcium phosphate, with less than 1 per cent. of combined iron oxide and alumina. The rock is very hard, however, and difficult to break up. An English company owns the property, and mining operations are being actively carried on at the Santa Barbara mines.

Before the war the bulk of the output was shipped to Germany and England.

Exports of Phosphates from Curaçao.

Year.	Quantity (long tons).
1913	39,000
1914	96,000
1915	30,805
1916	14,235
1917	3,524
1918	—
1919	9,890

United States.*

The United States is the largest producer in the world of phosphate-rock and manufactured superphosphates.

The southern States of Florida, South Carolina and Tennessee, have for many years been the main source of phosphate-rock in the United States, but recent investigations have shown that in addition to these deposits, there are large reserves of phosphate-rock in the States of Arkansas, Wyoming, Utah, Idaho and Montana.

In Florida four distinct types of phosphate-rock have been recognized, viz., land-pebble, hard-rock, soft-rock, and river-pebble. Of these the land-pebble deposits are the most important, and the hard-rock next in value, while the river-pebble beds are now no longer worked. The land-pebble and hard-rock varieties are exported largely. The soft-rock is worked for home consumption only.

The land-pebble deposits are of Pliocene age, and consist of a conglomerate of sand, clay and pebbles formed by marine action. They cover a large area in Polk and Hillsboro counties, occurring in beds from 8 feet to 20 feet in thickness. From 10 to 25 per cent. of the whole deposit is stated to be composed of phosphatic material. The average tri-calcium phosphate content of the marketed material ranges from 60 to 79 per cent. The deposits are worked by hydraulic methods after the removal of the overburden. The phosphates thus obtained are first

* The United States Geol. Surv. Mineral Resources (Annual). The Mineral Industry (Annual).

washed to remove a proportion of the sand and clay, and then passed through log-washers. The clean product is dried in kilns and then stored for shipment. Only the hard pebbles are recovered, practically all the soft phosphate going to the waste-dump.

The hard-rock phosphate occurs as boulders in a soft matrix of phosphatic sands and clays, the whole deposit resting on limestones of Lower Oligocene age. The principal hard-rock mining region extends in a belt from Suwanee, in the north, to Pasco county, in the south, a distance of over 100 miles. The hard-rock varies from a massive and compact structure, to a light and porous material, and ranges in colour from deep black to almost white. The phosphate content of the hard-rock deposits varies from 10 per cent. to more than 30 per cent. of the mass. Probably not more than 15 per cent. of the material mined can be considered of marketable value. Practically all the material sold is guaranteed to carry not less than 77 per cent. tri-calcium phosphate. After the removal of the overburden, usually by hydraulic methods, the phosphate-rock exposed is broken by pick and shovel if the deposit is dry, or by dredging methods if there is much water. The excavated rock is crushed, washed, and dried in kilns preparatory to shipment. During these operations it is estimated that twice as much phosphoric acid is wasted in the material sent to the waste-dump as is contained in the material sold.

Three types of phosphate deposits are recognized in Tennessee according as the material is brown, white or blue.

The brown phosphate is found abundantly in the south-west of the central Tennessee basin, notably in the vicinity of Mount Pleasant. The deposits occur either as residual products, or as blanket deposits, both of Ordovician age. Mining is carried out opencast by mechanical excavators or by tunnels driven into the hill-side. The broken rock is washed, screened, and sold under a guarantee of from 70 to 80 per cent. of tri-calcium phosphate.

The white phosphate is directly associated with Silurian limestone. There are three varieties, viz.: (1) *stony*, carrying less than 50 per cent. of tri-calcium phosphate; (2) *brecciated*, which consists of large masses of phosphate of lime cementing fragments of chert; and (3) *lamellar*, consisting of thin layers of phosphatic material derived from the overlying Devonian rock. Both the lamellar and the brecciated deposits carry as much as 85 per cent. tri-calcium phosphate.

The blue phosphate occurs in bedded deposits of Devonian age. The thickness of the beds varies from a few inches up to about 4 feet, but the high-grade rock is rarely more than 28 inches in thickness. After the overburden has been stripped the rock is excavated by mechanical shovels and crushed fine. The phosphatic content of the beds varies from 30 to 85 per cent. tri-calcium phosphate.

In South Carolina the phosphates occur in a belt, about 60 miles in length, between the source of the Wando river and the mouth of the Broad river. The deposits, which are probably of Miocene age, occur in beds from 1 to 3 feet in thickness, overlain by 3 to 18 feet of greensand marl. The rock is of comparatively low grade, containing from 55 to 58 per cent. of tri-calcium phosphate.

The western phosphate field covers an area of about 2½ million acres in the States of Idaho, Wyoming, Utah and Montana. The phosphate occurs as well-defined beds of exceptional regularity in rocks of Carboniferous age. The beds vary in thickness from 3 to 6 feet, and contain on an average over 65 per cent. of tri-calcium phosphate.

The United States Geological Survey is still engaged in examining these extensive deposits. It has been estimated that the reserves amount to more than 5,750,000,000 tons of high-grade rock within a depth of 5,000 feet from surface.

In addition to the occurrences in the regions mentioned, there are extensive deposits of phosphate-rock in Independence county, Arkansas, where the mineral occurs in beds from 4½ to 6 feet in thickness, in Ordovician rocks. Manganese ore is commonly associated with this phosphate-rock which carries from 56 to 71 per cent. of tri-calcium phosphate. The rock is mined by means of adits and drifts, and the produce is sold locally.

Production and Sales of Phosphate-Rock in the United States.

Year	Production.	Sales.	
	Quantity (long tons).	Quantity (long tons).	Value* (£).
1913	3,152,208	3,111,221	2,457,548
1914	2,649,174	2,734,043	2,001,675
1915	1,935,341	1,835,667	1,127,802
1916	2,169,149	1,982,385	1,228,540
1917	2,851,886	2,584,287	1,618,976
1918	2,284,245	2,490,760	1,711,346
1919	1,851.549	2,271,983	2,414,847

Exports of Phosphates from the United States.

Year	Quantity (long tons).				Total Value* (£).
	Hard Rock.	Land Pebble.	All Other.	Total.	
1913	473,533	891,263	1,712	1,366,508	2,082,621
1914	281,806	681,241	1,067	964,114	1,410,761
1915	34,572	218,472	377	253,421	344,136
1916	28,631	214,358	689	243,678	240,915
1917	12,403	138,010	15,945	166,358	173,968
1918	57,771	64,559	21,561	143,891	190,101
1919	215,039	128,860	34,832	378,731	743,330

* Values converted to £ sterling at the rate of 1 dollar=4*s.* 2*d.*

Exports of Phosphate-Rock (Land-Pebble) from the United States (Domestic Produce).

(Fiscal years ending June 30.)

To	Quantity (long tons).					
	1914.	1915.	1916.	1917.	1918.	1919.†
United Kingdom ...	159,220	93,112	86,015	39,033	37,215	45,991
Canada	118	3,000	3,734	4,004	5,545	1,202
Australia	—	5,132	—	—	—	—
Total to British Possessions	159,338	101,244	89,749	43,037	42,760	47,193
Austria-Hungary ...	3,000	—	—	—	—	—
Belgium...	129,537	11,800	—	—	4,769	—
Denmark	6,200	9,000	—	—	—	17,943
France	159,927	5,900	14,537	14,536	10,438	—
Germany	122,316	5,550	—	—	—	—
Italy	114,601	22,055	2,864	6,069	1,440	—
Netherlands	124,579	15,084	45,289	28,686	—	26,953
Portugal	4,800	—	3,500	—	—	—
Spain	53,928	51,839	75,987	61,897	32,359	16,072
Sweden	34,400	—	23,280	17,867	4,357	12,250
Cuba	—	—	—	6,002	14,786	8,449
Japan	88,004	—	—	—	—	—
Total to Foreign Countries	841,292	121,228	165,457	135,057	68,149	81,667
TOTAL	1,000,630	222,472	255,206	178,094	110,909	128,860
	Value (£).*					
United Kingdom ...	192,754	112,192	88,192	27,416	31,841	70,022
Canada	117	3,750	4,222	3,173	4,481	1,001
Australia	—	5,346	—	—	—	—
Total to British Possessions	192,871	121,288	92,414	30,589	36,322	71,023
Austria-Hungary ...	3,750	—	—	—	—	—
Belgium	159,419	14,021	—	—	3,527	—
Denmark	7,750	10,000	—	—	—	33,703
France	196,584	7,375	11,037	8,051	8,703	—
Germany	144,614	6,312	—	—	—	—
Italy	139,491	25,423	3,580	3,414	900	—
Netherlands	152,454	17,481	53,011	27,246	—	38,595
Portugal	6,000	—	4,375	—	—	—
Spain	65,410	64,092	85,972	54,796	31,556	22,613
Sweden	43,000	—	25,627	18,388	5,011	15,618
Cuba	—	—	—	4,443	9,060	6,845
Japan	109,067	—	—	—	—	—
Total to Foreign Countries	1,027,539	144,704	183,602	116,338	58,757	117,374
TOTAL	1,220,410	265,992	276,016	146.927	95,079	188,397

* Values converted to £ sterling at the rate of 1 dollar=4*s.* 2*d.*

† Calendar year.

Exports of Phosphate-Rock (High-grade Hard-Rock) from the United States (Domestic Produce).

(Fiscal years ending June 30.)

To	1914.	1915.	1916.	1917.	1918.	1919.†
	Quantity (long tons).					
United Kingdom ...	19,658	6,110	—	—	1,850	—
British Honduras ...	—	—	5	—	—	—
Canada	—	—	147	300	235	752
Total to British Possessions	19,658	6,110	152	300	2,085	752
Austria-Hungary ...	23,466	—	—	—	—	—
Belgium	19,405	—	—	—	—	16,161
Denmark	19,200	5,302	4,400	—	—	80,753
France	3,200	—	—	—	—	—
Germany	241,560	17,838	—	—	—	28,062
Italy	10,210	—	—	—	—	—
Netherlands	98,623	3,008	—	—	—	10,702
Norway	—	—	—	3,104	8,356	18,517
Portugal	4,800	760	5,663	—	—	—
Spain	20,493	3,421	5,920	—	—	18,527
Sweden	14,720	9,566	28,195	11,559	13,551	37,106
Switzerland	—	—	—	—	—	2,575
Mexico	—	—	—	—	10	—
Cuba	—	—	—	—	45	1,884
Total to Foreign Countries	455,677	39,895	44,178	14,663	21,962	214,287
TOTAL	475,335	46,005	44,330	14,963	24,047	215,039
	Value (£).*					
United Kingdom ...	40,954	12,729	—	—	1,927	—
British Honduras ...	—	—	10	—	—	—
Canada	—	—	312	751	732	2,957
Total to British Possessions	40,954	12,729	322	751	2,659	2,957
Austria-Hungary ...	48,887	—	—	—	—	—
Belgium	40,427	—	—	—	—	33,669
Denmark	40,000	11,046	9,167	—	—	172,608
France	6,667	—	—	—	—	—
Germany	503,250	37,162	—	—	—	62,663
Italy	21,271	—	—	—	—	—
Netherlands	205,465	6,267	—	—	—	27,947
Norway	—	—	—	6,467	12,752	41,883
Portugal	10,000	1,583	11,798	—	—	—
Spain	42,694	7,127	12,333	—	—	41,720
Sweden	30,667	19,929	55,782	24,137	20,766	78,135
Switzerland	—	—	—	—	—	51,217
Mexico	—	—	—	—	22	—
Cuba	—	—	—	—	128	4,420
Total to Foreign Countries	949,328	83,114	89,080	30,604	33,668	468,262
TOTAL	990,282	95,843	89,402	31,355	36,327	471,219

* Values converted to £ sterling at the rate of 1 dollar = 4*s.* 2*d.*

† Calendar year.

Exports of all other kinds of Phosphate from the United States (Domestic Produce).

(Fiscal years ending June 30.)

To	Quantity (long tons).					
	1914.	1915.	1916.	1917.	1918.	1919.‡
United Kingdom ...	—	—	—	—	2,500	1
British Honduras ...	—	2	—	1	—	1
Canada	1,856	885	337	2,865	8,824	5,303
British West Indies ...	—	—	—	—	298	126
Australia	—	—	—	—	500	—
Total to British Possessions	1,856	887	337	2,866	12,122	5,431
Netherlands	50	—	—	2,182	—	3,500
Norway	—	—	—	—	3,975	2,200
Mexico	—	—	—	—	1	2
Cuba	—	—	—	1,460	6,525	4,156
Dutch East Indies ...	—	—	13	—	—	—
Other Foreign Countries	—	—	—	—	—	19,543†
Total to Foreign Countries	50	—	13	3,642	10,501	29,401
TOTAL ...	1,906	887	350	6,508	22,623	34,832
	Value (£).*					
United Kingdom ...	—	—	—	—	2,604	1
British Honduras ...	—	1	—	2	—	1
Canada	1,282	1,225	619	5,845	17,426	14,783
British West Indies ...	—	—	—	—	605	622
Australia	—	—	—	—	1,250	—
Total to British Possessions	1,282	1,226	619	5,847	21,885	15,407
Netherlands	76	—	—	4,318	—	12,396
Norway	—	—	—	—	4,969	3,668
Mexico	—	—	—	—	25	15
Cuba	—	—	—	3,895	14,532	15,454
Dutch East Indies ...	—	—	18	—	—	—
Other Foreign Countries	—	—	—	—	—	36,773†
Total to Foreign Countries	76	—	18	8,213	19,526	68,306
TOTAL ...	1,358	1,226	637	14,060	41,411	83,713

* Values converted to £ sterling at the rate of 1 dollar = 4*s.* 2*d.*
† Including Belgium, Denmark and Sweden.
‡ Calendar year.

French Guiana.

Deposits of phosphate-rock on Grand Connétable Island have been worked for many years by an American company. The average annual output for the period 1910 to 1913, inclusive, was about 6,000 tons. Production has declined since that date, and the deposit appears to be approaching exhaustion.

Japan.*

For many years beds of low-grade phosphate of lime have been worked in the provinces of Noto, the Bonin Islands, and in Formosa, but the quantity of phosphate obtained has been small. Important deposits occur on the island of Rasa, one of the Lu-chu Islands, but examination has shown that these carry a high percentage of iron oxide and alumina, which renders their use for the manufacture of superphosphate difficult and expensive.

Japan now controls the important deposits of rock-phosphate on Angaur Island, one of the Pellew group, formerly a German possession. From two to three million tons of high-grade rock are estimated to be contained in the deposits on this island, which are now worked to supply the Japanese fertilizer factories.

The Japanese also possess considerable reserves of rock-phosphate in the deposits known to occur on several of the Marshall Islands and on Fais Island in the West Caroline group. The Marshall Islands deposits were formerly worked by the Germans, but both these groups of islands passed to Japan under the terms of the Peace Treaty.

Japanese Production and Imports of Phosphates.

Year	Production of Phosphates.		Imports of Phosphorite.
	Quantity (long tons).	Value† (£).	Quantity (long tons).
1913	18,737	28,915	
1914	37,644	50,818	
1915	56,788	59,938	133,666
1916	112,965	125,080	98,159
1917	119,673	130,545	153,041
1918	189,181	711,739	88,186
1919	120,893	477,563	188,573

† Values converted to £ sterling at the rate of 10 Yen=£1.

Production of Phosphates in Formosa.

Year.	Quantity (long tons).
1913	5,531
1914	1,317
1915	495
1916	1,476
1917	—
1918	
1919	

* Statistical Reports of the Department of Agriculture and Commerce, Japan (Annual).

Production of Phosphate-Rock in Angaur Island.

Year.	Quantity (long tons).
1913	88,500
1914	59,000*
1915	29,500
1916	29,500
1917	
1918	
1919	

* Exports.

Makatea.†

The Compagnie Française des Phosphates owns the exclusive mineral rights on the island of Makatea. The phosphates occur at the surface, and are broken by pick and shovel, the excavated material being crushed, dried, and sold on a moisture percentage basis. The rock contains about 80 per cent. of tri-calcium phosphate, and is now shipped chiefly to New Zealand.

Exports of Phosphates from Makatea and New Caledonia.

Year.	Makatea.		New Caledonia.	
	Quantity (long tons).	Value‡ (£).	Quantity (long tons).	Value‡ (£).
1913	80,737	65,645		
1914	71,753	58,340	2,361	4,800
1915	70,571	57,379	2,755	4,200
1916	38,654	31,428	2,424	5,914
1917	31,741	26,181	5,909	14,414
1918	39,000			
1919	39,000			

‡ Values converted to £ sterling at the rate of 25 francs=£1.

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